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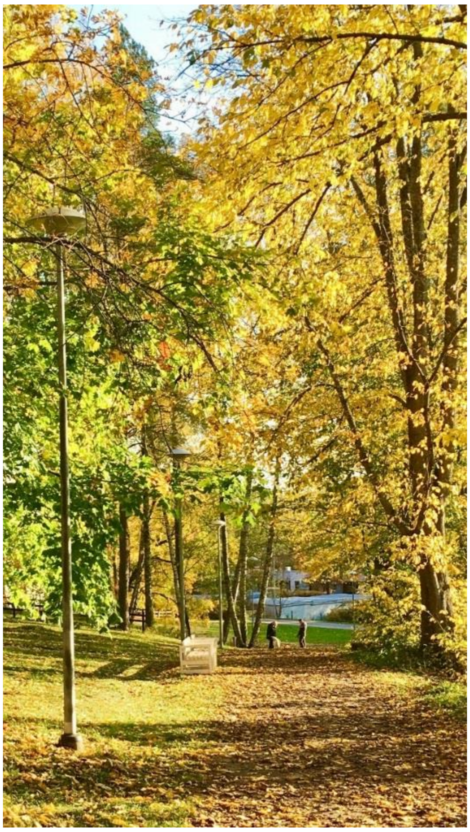

Energy efficiency: can we easily compare countries?

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Summary

Why does energy efficiency in Finland compare to other countries as it does? In this study, we aim to find the factors that help explain the discrepancies between expected and received results, especially results shown by recent IEA, JRC and ODYSSEE decomposition analyses and by new ODYSSEE and MURE country comparison scoreboard tools. The results of the decompositions differ a lot, even when using same source data and same timeline and reasonably similar decomposition structure. This goes to show that an energy efficiency calculation is not easy or just a matter of course, but includes a lot of pitfalls and caveats. One issue is the handling of missing time series or data values. To help readers of energy efficiency country comparisons, we request that the basic principles used to handle missing values should always be documented. Especially the chosen industry decomposition structures do not perform so well for Finland due to too aggregate data, e.g. by including services in industry in IEA and JRC. More disaggregate designs would improve Finnish positioning considerably. For example, to analyse Finnish industry properly, the pulp and paper sub-sector must be disaggregated to an adequate product level.
The ODYSSEE and MURE scoreboards results for Finland can be debated and especially the selection of indicators such as, e.g., value added, which, according to IEA, is not such a good energy efficiency indicator, for main part of the industry, energy per passenger for air flights and penetration of solar heaters in houses for hot water. The Finnish trend score is also not very good, but here one reason might be the good starting point. It is very hard to put up 50% or 60% improvements in the industry in 15 years as, for example, some Eastern European countries do. Finnish ranking in MURE Policy scoreboard is not bad, but many scrutinized policy measures by other countries in the database raise question marks, especially their impact estimates.
The title of the report is a question: Energy efficiency: can we easily compare countries? The short answer is no, and this study tells why not.

Confidentiality	Public

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Preface

VTT Technical Research Centre of Finland Ltd made in the fall of 2018 for Motiva this study of recently published energy efficiency country comparisons, both decomposition analyses by IEA, JRC and ODYSSEE as well as ODYSSEE and MURE Scoreboards. The target was to find out why Finland compares to other countries as it does. The steering group consisted of Ulla Suomi and Lea Gynther from Motiva Oy and Heikki Väisänen and Johanna Kirkinen from Energy Authority of Finland, who financed the project via Motiva Oy. The author wants to thank all parties for their input, viewpoints and their patience. The effort to dive deep into energy efficiency analyses was greater than anticipated, as it turned out that the devil is in the details.

Espoo 31.12.2018

Göran Koreneff

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EXECUTIVE SUMMARY

Recently, decomposition results by JRC, IEA and ODYSSEE have been presented. These and ODYSSEE and MURE scoreboards are now used to compare nations with each other. This study has looked at the methodologies and data used and at the results. Why does energy efficiency in Finland compare to other countries as it does? In this study, we aim to find the factors that help explain the discrepancies between expected and received results of the decompositions and scoreboards.

IEA (2014) notes that energy intensity is often used as a proxy for energy efficiency and exclaims that it is a mistake, as for instance, a small service-based country with a mild climate would certainly have a much lower intensity than a large industry-based country in a very cold climate, even if energy is more efficiently consumed in this country than in the first.

According to IEA (2014), efficiency is a contributing factor in intensity, but many other elements – often more significant – also need to be considered. These include: the structure of the economy (presence of large energy-consuming industries, for instance); the size of the country (higher demand from the transport sector); the climate (higher demand for heating or cooling); and the exchange rate.

It must be noted, that Finland, and Sweden, for that matter, fulfil these circumstances to a dot. Finland is the EU-28 country with the highest share of industry in final energy consumption (ODYSSEE 2018c), around 45%, see Figure 1. Finland is also by far the coldest EU-28 country.

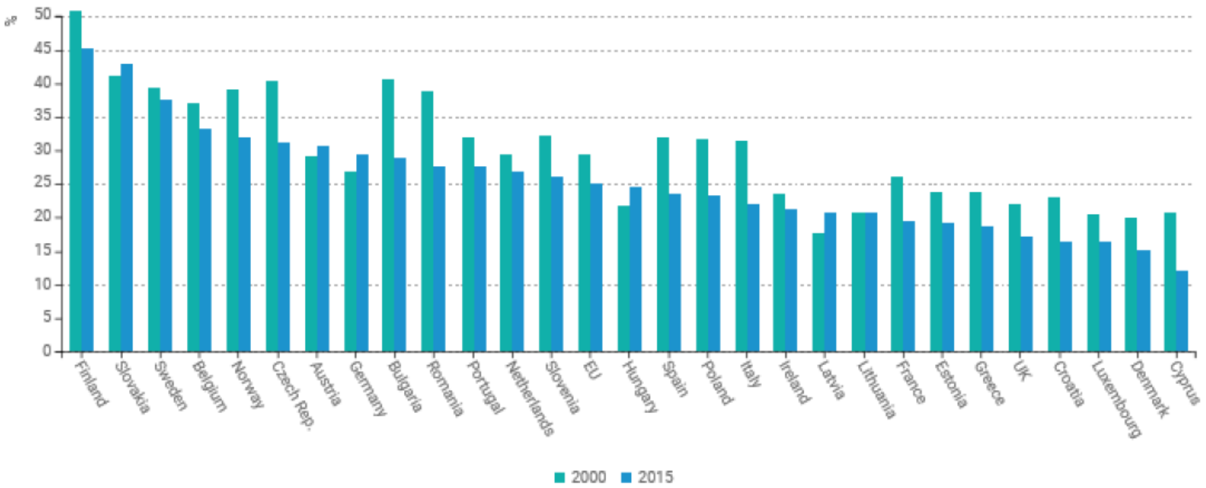


Figure 1. Share of industry in final consumption. (ODYSSEE 2018c)

Data issues

IEA (2017b) states that important validation criteria include internal consistency, consistency with external data sources, and plausibility (values of indicators need to fall within expected ranges to be meaningful). As there is serious data issues, both regarding correctness, continuity, and availability at desired disaggregate level, the results of all studies should be read with caution. The indicator definitions used in the analyses are not always the best ways to estimate change in energy efficiency and energy savings. Data availability might be the main driver behind that.

Not all needed data is available. Time series can be missing altogether or be inhabited sparsely with values. What more, how are missing data points or data sets managed? ODYSSEE stays totally mum on the subject, which is not very helpful. It would be very important to divulge the basic rules and guidelines used. For example, it seems countries which have no data in the database fare better than Finland in the scoreboards, even as

Finland itself does pretty well. Should we in a country comparison scoreboard really allow for countries with non-existent data to perform very well, or, on the other side, very badly, or just leave them out of the comparison?

The disaggregate level of data used is a major issue. To get understandable and working indicators, we would need a deep and very detailed disaggregate level. For example, energy intensive sub-sectors should be separated and analysed based on production at an adequate level. On the other hand, the deeper we try to burrow into the data, the less trustworthy it becomes, e.g. splitting electricity consumption into large appliance unit consumptions etc. on an annual basis. It would be hard to say that any of the sources is very successful in all of its choices.

IEA has published the issues that countries have with the data quality they have delivered. There is a lot of issues, and for example most countries have announced that they are doing or will do something with their transportation data inputs. ODYSSEE has quite well disaggregated and reasonably comprehensive data, with data collection and data structure (and energy efficiency indicator) development going on for years, so it has an advantage to Eurostat or IEA data. However, there is still inconsistencies in the data, missing values or time series, and looking over longer periods, there are time series break points where data definitions have changed.

Energies for industrial combined heat and power production are treated correctly by IEA and for the electricity production part also by ODYSSEE, but here sold heat seems to be mistreated. The energy used for sold heat is left to burden the industry.

What is lacking is a documentation of how direct use of distributed energy sources are handled in the databases and in the calculations. It is also doubtful that individual countries follow same guidelines for their inputs.

Decompositions

Decomposition is an approach that is actually easy to understand and comprehend. Changes in energy use are divided into activity, structure and energy efficiency effects, and these results give valuable insights. Whereas IEA and JRC use a mathematically sound decomposition method, ODYSSEE decomposition is more of a hotchpotch of individual indicators with a substantial residue, which reduces the degree to which one can rely on the presented effects being correct. ODYSSEE is mainly relying on the concept of a “technical” indicator for savings, i.e. an indicator that only allows for positive developments that increase savings, ODEX. ODYSSEE (2018b) uses Figure 2 as an affirmative of the logic.

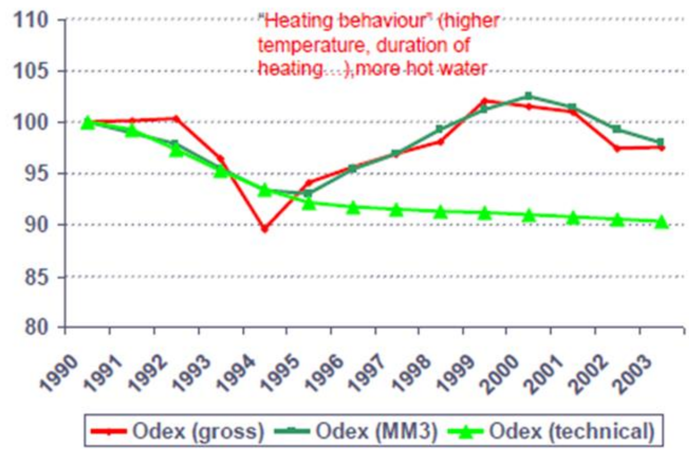


Figure 2. The purported rationale for using technical Odex. (ODYSSEE 2018b)

The rationale for technical ODEX is given as:

> "In some countries, there is a slow down or even a deterioration of energy efficiency progress for heating since the mid-nineties. In a few other countries, there is even an overall increase in the ODEX since 1990. Such changes should not be interpreted as a reduction of energy efficiency, as technical savings have not actually stopped, with all the extra policy measures implemented in the late nineties and the continuous addition of new dwellings that are much more efficient. This situation rather reflects negative behavioural savings, due to higher indoor temperature. This means that the actual energy efficiency progress is under estimated, with the standard calculation of the ODEX …To separate out the influence of behavioural factors, a technical ODEX is calculated and used to measure the energy efficiency progress…The difference between the technical ODEX and the gross ODEX shows the influence of behavioural factors."

A better (in author's view) explanation is that the economic recession, which started in the early 90's induced the energy conservation, which was then gradually phased out as household incomes returned to pre-recession levels, and first then we are seeing also energy efficiency improvements. Methodologically, ODYSSEE is clearly on the losing end in the decomposition comparison.

Overall, IEA, JRC and ODYSSEE decomposition results differ a lot, but this might partly be due to slightly different time periods. For clarity, we compare JRC and ODYSSEE results for the same time period, 2005-2015, see Table 1. The differences are partly huge.

Table 1. Sector energy savings 2005-2015 from ODYSSEE (2018a) and JRC (2017)

	Households		Industry	Services	Commer-cial	Transport			
						Passenger		Goods	
	ODYSSEE	JRC	ODYSSEE	ODYSSEE	JRC	ODYSSEE	JCR	ODYSSEE	JCR
AT	13 %	7 %	10 %	23 %	16 %	4 %	-1 %	8 %	10 %
DK	18 %	23 %	19 %	4 %	22 %	7 %	5 %	6 %	11 %
CY	24 %	20 %	29 %	39 %	-6 %	10 %	-11 %	0 %	-43 %
FI	**5 %**	**20 %**	**6 %**	**4 %**	**-2 %**	**4 %**	**-5 %**	**0 %**	**-26 %**
FR	18 %	21 %	7 %	9 %	13 %	5 %	6 %	4 %	8 %
BE	22 %	37 %	14 %	0 %	7 %	9 %	2 %	16 %	-10 %
EL	20 %	15 %	11 %	8 %	-8 %	26 %	33 %	0 %	-8 %
DE	23 %	25 %	9 %	7 %	9 %	10 %	5 %	13 %	6 %
IT	6 %	-2 %	15 %	1 %	19 %	13 %	17 %	4 %	-37 %
IE	37 %	37 %	20 %	23 %	26 %	8 %	29 %	2 %	-159 %
LU	13 %	43 %	1 %	36 %	3 %	3 %	13 %	0 %	-60 %
NL	30 %	28 %	20 %	14 %	19 %	9 %	-1 %	0 %	-1 %
PT	28 %	27 %	17 %	23 %	16 %	15 %	-9 %	8 %	3 %
ES	27 %	11 %	15 %	23 %	19 %	11 %	-20 %	12 %	19 %
SE	27 %	18 %	5 %	41 %	19 %	11 %	8 %	5 %	-10 %
UK	34 %	35 %	16 %	26 %	19 %	11 %	-3 %	0 %	-3 %

Transport

Looking, for example, at a sector using the same source data, transport, JRC and ODYSSEE present quite different decomposition results, with ODYSSEE results being "technically" unrealistic and implausible.

Industry

To analyse industry energy use based on added value as JRC and IEA do is an easy solution, but not a very good one, as already noted. For example, for Finland the ending of Nokia Phones - high value added, small energy use- makes a sad impact on the perceived energy intensity.

To combine industry, agriculture and especially service sectors (IEA, JRC) is also totally unnecessary and makes the results less useful. Service sector is generally 10 to 20 times larger than the next largest sub-sector, measured in value added, so it totally dominates the results.

However, ODYSSEE separates between industry, service and agriculture sectors and, in addition, looks at energy intensive sub-sectors paper, steel and cement based on physical production. That is an improvement, but not enough; the disaggregate level is not low enough. Pulp production tons are not used at all, only paper tons, which clearly gives a skewed result. Finland for example exports 27% of the pulp production and most of it to Europe. In addition, to produce pulp from recycled fibres uses 90%-95% less energy than chemical pulp from virgin fibres, so we can’t really compare two countries without knowing what kind of pulp and paper is produced. For steel, oxygen blown converter and electric arc furnace productions are not separated either, although they have different BAT unit consumptions.

Households

Households are also not so easy to assess. The definitions of heating degree days differ, space heating corrections to normal climate might be lopsided, e.g. negatively for Finland and positively for Sweden, see Figure 3. Please note that Swedish heating demand seems to be pre-corrected, as it does not react as heat degree days suggest. Large appliance data (IEA, ODYSSEE), which has a lower trustworthiness in author’s mind, is not available for all countries. How is missing data handled and is the solution fair? JRC uses gross disposable income as the denominator for household electricity use. This improves Finnish results, but is it really fair and related to energy efficiency and not to economic prosperity? For example, Italy who fares badly could with a good conscience let out a righteous yelp.

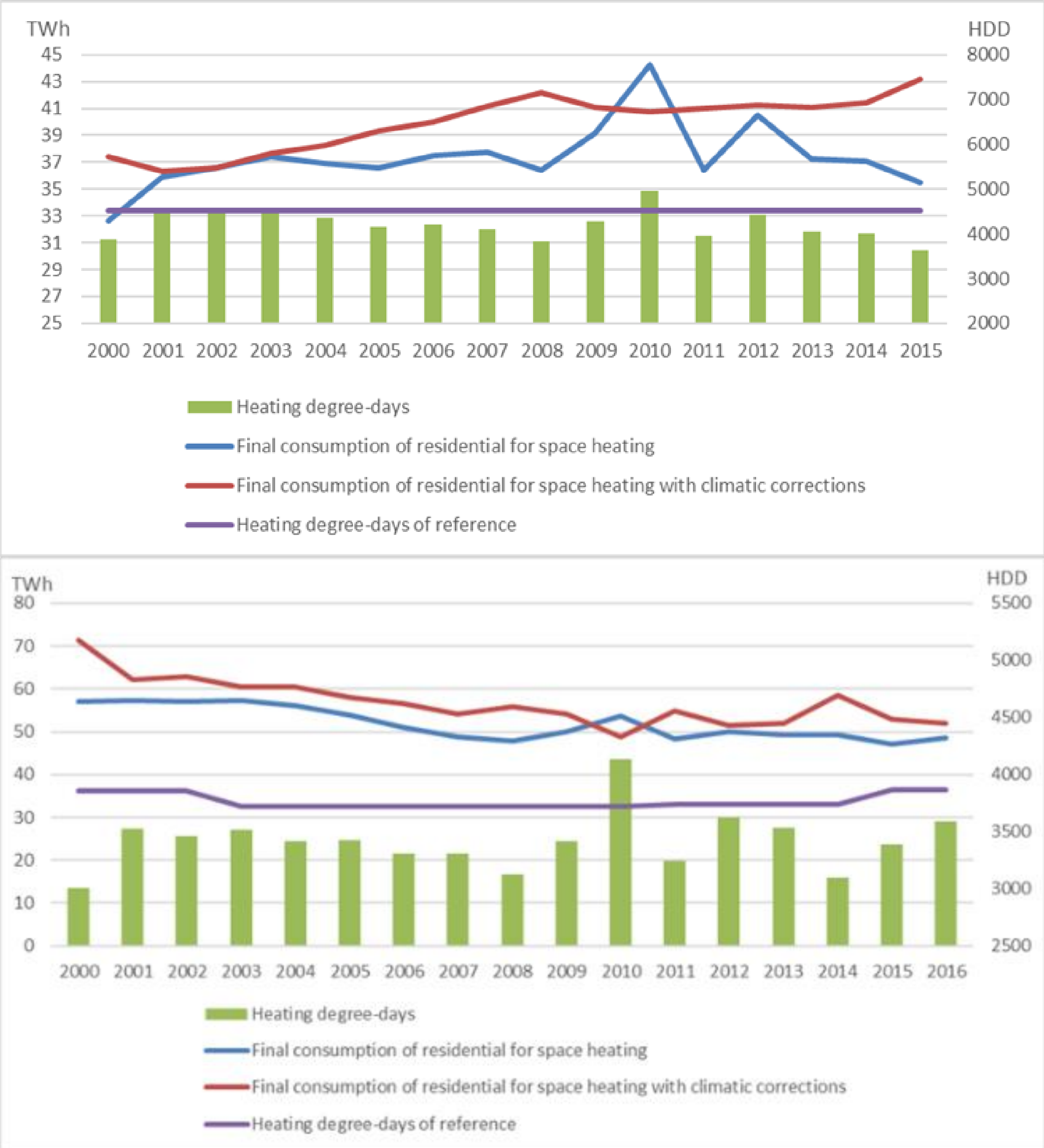


Figure 3. Overcompensating heating demand from extreme years (blue line) to normal years (red line), Finland on top and Sweden below. (Data source: ODYSSEE 2018d)

ODYSSEE Scoreboards

ODYSSEE scoreboard was also analysed. There are scoreboard for energy efficiency level, trend and their combination. Combining level and trend scores is done with equal weights, which does not feel fair in many cases. Trend is mainly a proportional change. If the level to begin with is not so good, it is easier to achieve a large change than from a state-of-the-art level. The scoreboard, however, is evaluating a 10% improvement from a bad level as highly a 10% improvement from the state-of-the-art level. This could be debated.

As with the decomposition, there is no clue as to how missing data is managed. This severely hampers the trustworthiness of the scoreboards' results. As country points for individual indicators are scored in relation to worst and best case, outlying worst or best cases compress the evaluations for all other countries. A good country does not get the point difference it deserves compared to a mediocre country. Some values are different in the database compared to the scorecard with distorting effects (e.g. outlier good value for UK car efficiency).

The selection of indicators is also partly dubious. For example:

- Car efficiency is measured in l/100 km. Litre is not an energy unit and feels a bit misplaced here. And it raises questions. For example, how is electric vehicle consumption converted to litres, is it to diesel or gasoline litres?
- Solar heat penetration is used as an independent indicator, but it itself already reduces energy need for hot water. Is it not a redundancy to use it also as a separate indicator? Use of solar water heaters feels also a bit lopsided. They are more economical in the Mediterranean area with better solar conditions than in Northern Europe. Penetrations of air-water, exhaust air and ground source heat pumps are not used in parallel. Why not, wouldn't it be a fairer approach?
- For Finland and Sweden, as pulp & paper represents around half of the total industrial consumption, the adjusted indicator is based on physical quantities instead of value added. However, only paper, not pulp, production is used. This methodological shortcoming seriously affects the comparability and usability of the results.
- Industry (except pulp and paper) is based on added value, which is a not so good indicator. For example, the rise and demise of Nokia phones has a really bad statistical effect on industry energy efficiency trend score.
- Air transport is evaluated as energy per passenger. . It is hard to see why this indicator has been selected. Is this really a fair method, as some are situated in the periphery, a long way from Brussels, while others are in the middle of Europe? What more, data reveals that this includes both domestic and international flights, and Finnair of Finland has massively with long-distance (and thus energy consuming) flights to Far East.
- Service sector space heating is estimated per employee. This does not measure energy efficiency but labour policies and automation etc. Floor area would have been better.

MURE and Combined Scoreboard

After a swift analysis of only nine of 2400 measures used by MURE policy scoreboard, grave doubts on the presented end-user sector energy savings have arisen. Most measures concern the energy transformation sector and their effects can be seen in primary energy use, but at best only lightly touch upon end-user sectors. However, as cross-sector measures, the savings are fully seen in the scores of all the sectors. So, end-user savings are exaggerated. And there are other data issues.

Finland fares well in most sectors' policy scoreboards, but Sweden does not. Sweden is among the last countries. That is not believable. The variation in data input quality and quantity tells us that we really should be careful about ranking countries based on the data.

The Combined scorecard gives equal weights to ODYSSEE level, ODYSSEE trend and MURE Policy scoreboards. The credibility of each of these scoreboards differ, so not such a good idea. Actually, these scoreboards should not be combined, as they differ qualitatively and from the content are, or should be, redundant.

Finland's overall ranking is 24th of 29, with industry at 24th place, transport at 20th, households at 7th and services at 28th. As can be shown, in many cases Finnish ranking would and should be higher but methodological weaknesses or data uncertainties and revisions gave another result. So, an official ranking of countries should not be done as the results are ever so often too far from the "truth".

Recommendations

The political demand, and thus the drive, is pushing hard for easy, one-number-says-all, comparative indicators and ranking systems of the energy efficiency development and level of a country. That is the reason why the energy efficiency research community should be careful and actually not present such. The rankings and indicators are all flawed, some more, some less, and full of caveats. To compare countries with each other is something that should not be made without excellent and detailed tools. The ODYSSEE Scoreboard is too simplified and misaligned to present a trustworthy result. Overall, the tool for ranking of countries is really dangerous in the hands of the public and especially politicians, as they probably will not be aware of all the caveats and errors and might make incorrect and costly decisions based on the scores

Nevertheless, ODYSSEE and MURE Scoreboards form a great introduction to the world of energy efficiency. To present all the countries in one picture should actually be the beginning of the journey into energy efficiency comparisons, not the end. To see how one's country compares to others should induce the interest to go deeper, find out the reason why.

Some recommendations for quick improvements:

- add explanations of how missing data and data series are handled,
- add explanations on the indicators used and the data behind them,
- change indicators in use, especially for the ODYSSEE scoreboards,
- do not use equal weights for trend and level and/or readjust trend to take into consideration the level,
- add warnings that any results are not the truth but one view,
- skip the Combined ODYSSEE&MURE Scoreboard, and
- stop using technical ODEX.

The title of the report is a question: Energy efficiency: can we easily compare countries? The short answer is no.

1. Introduction

Why does energy efficiency in Finland compare to other countries as it does? In this study, we aim to find the factors that help explain the discrepancies between expected and received results, especially results shown by the new ODYSSEE-MURE country comparison scoreboard tools. The scoreboards are ranking the countries according to energy efficiency level, trend and the combined effect, as well as according to energy saves by policy measures or compared to potential or saving target. In addition, a third tool gathers the level, trend and energy saving policies into a Combined scoreboard.

The target of this study is to assess the results of these scoreboards and especially from a Finnish point of view. As Finland usually is among the not so successful candidates, does this correspond with reality or are there methodological selections or data reliability/usability issues that reduce the reliability of the results? For example, different countries have different heating habits. How will these habits affect energy efficiency and how should they affect energy efficiency evaluations?

The analysis will also include a thorough examination of the decomposition analyses results by IEA, JRC and ODYSSEE. How do they compare and is there differences that can be explained by methodology etc.? Selected decomposition methods and results for the industry, households, transport and services will be analysed and their benefits and drawbacks noted.

In addition, this study will ponder on why we do energy efficiency comparisons and if indicators, decompositions and scoreboards are useful tools for the assessment of energy efficiency.

2. Decomposition methods

2.1 What is energy efficiency

What is then energy efficiency? As IEA (2014) notes:

> Although a precise definition for energy efficiency is not fundamental for working on energy efficiency indicators and for the rest of the manual, what is provided by the Lawrence Berkeley National Laboratory seems to be an accepted definition: energy efficiency is "using less energy to provide the same service".

This example from IEA (2014), though originally from EIA, gives a good picture of the problems with achieving a good definition:

> A sign says: ***"Take the stairs – be more efficient***
>
> Person A interprets the sign as the "true" definition of energy efficiency. To Person A, the elevator is not being used. They are still getting to where they want to go and are using less energy in doing so.
>
> Person B considers the fact that they are not getting to where they are going with the same ease. They do not believe that they are being energy efficient, but instead they believe that they are "conserving energy" at a reduced level of service – they have to walk instead of ride.
>
> When it comes to trying to define "to be energy efficient" or "energy efficiency", there does not seem to be a single commonly accepted definition of energy efficiency. Along the lines of Person B's thinking, it is generally thought that an increase in energy efficiency is when either energy inputs are reduced for a given level of service, or there are increased or enhanced services for a given amount of energy inputs.

Much depends on the definition of service. And here, one important aspect is if someone else has the right to set boundaries for the service. As energy conservation or energy saving are also desired goals, can we rule some of those actions out just because the resulting service, e.g. indoor temperature, is not up to par for us?

2.2 What do we need decomposition for

Changes in energy use of a sector are per se generally not that informative indicators. If we can divide the change into separate factors, the informative value is much greater. The most common factors are activity, structure and intensity effect, where intensity effect is used as an inverse indicator of energy efficiency. The lower the intensity effect, the better the energy efficiency. For example, for household heating, activity could be represented by the population, the structure by residential square meters per population and the intensity by household heating energy in relation to residential square metres. The decomposition could also be done using for example the number of dwellings as activity and residential m^2/dwelling as structure. Weather is also an important factor for explaining differences in energy use between years, so the heating energy should be corrected to express a normal climatic year.

For a better understanding of decomposition, a short introduction to the basic idea of decomposition is given here, with the more widely used general methods Laspeyres and

Logarithmic-Mean Divisia Index (LMDI) presented. In addition, we take a closer look at the ODYSSEE decomposition method(s).

2.3 What is decomposition about

The JRC report (Economidou 2017) assessing energy efficiency targets using index decomposition analysis gives a nice overview of decomposition and the basics. According to it, decomposition analysis has been widely used to study the driving forces behind changes in energy- and emission-related trends in a given time period. Two of the most popular types of decomposition techniques include the index decomposition analysis and structural decomposition analysis. The main difference between these two types lies in the input data used: the structural decomposition analysis method uses the input-output model to decompose the evolution of indicators, whereas the index decomposition analysis uses only sectoral data. In this report, we will not look at primary energy but focus on sectoral index decomposition analysis.

The basics of analysis is to form a decomposition identity such that the parts add up to the whole. Sector energy use in year t can be written as

$$E_t = At \sum_j S_{jt} I_{jt}$$

where

E_t is the sector's energy use in year t,
A_t is the sector's activity (e.g. measured as Value added) in year t, and
S_{jt} is the sub-sector j's specific activity in relation to the sector's activity in year t, and
I_{jt} is the sub-sector j's energy intensity[1], i.e. energy use per specific activity.

Activity, structure and intensity effects are each calculated by keeping the other effects stable, e.g. at the level of the reference year ($t=t_0$). Here we can use different methods, for example the Laspeyres method or the Logarithmic-Mean Divisia Index (LMDI).

2.3.1 Laspeyres method

The Laspeyres index method has been widely used both globally, e.g. earlier by IEA, and also in Finland, see Shipper&Perälä 1995, Koreneff&Elväs 2007, Gynther et al. 2010.

For example, the intensity effect in year t is calculated by keeping the structure and activity constant, i.e. at reference year t_0 level

$$E_{I,t}= A_{t0} \sum_j S_{j,t0} I_{j,t}$$

An index is achieved by dividing each effect with the energy consumption of the reference year, E_{t0}. The reference year can be kept constant or index calculations can be chained so that the reference year is always the previous year, t-1.

The multiplication of the effect indices does not match the energy use index, as there will be a residual effect $E_{R,t}$ or formulated as index, the residual term $E_{R,t}$ / E_{t0}:

[1] Energy intensity is often understood as energy use per monetary value, e.g. GDP or Value Added, but here we use a broader definition of intensity as the activity can be also something else, e.g. tonnes of steel or pulp and paper, square meters, tonne-km or person-km.

$$\frac{E_{A,t}}{E_{t0}} \times \frac{E_{S,t}}{E_{t0}} \times \frac{E_{I,t}}{E_{t0}} \times \frac{E_{R,t}}{E_{t0}} = \frac{E_t}{E_{t0}}$$

The benefit of the Laspeyres method is that it is very easy to understand and straightforward, but it leaves a residue. (Ang&Liu 2007)

The residual is usually assumed to be small, but especially with larger use changes it can possibly become substantial. In the sectoral and sub-sectoral analyses performed for Finnish energy use (Koreneff&Elväs 2007), the residual term was around 1.1 for industry as well as for manufacturing industry sectors and 0.92 for service sector, but negligible for households and transport sectors.

2.3.2 Logarithmic-Mean Divisia Index

In the Logarithmic-Mean Divisia Index (LMDI) method, the activity, structure and intensity effects are calculated using more complex formulas involving logarithms and exponential functions. However, there are benefits as is noted in the JRC report (Economidou 2017) based on (Ang & Choi 1997, Ang 2015):

1. It results in perfect decomposition, i.e. the results do not contain any residual term;
2. It can investigate the effect of more than two factors;
3. There is a simple relationship between multiplicative and additive forms[2];
4. Its consistency-in-aggregation property means that the estimates of an effect at the subgroup level can be aggregated to give the corresponding effect at the group level;
5. It does not increase in complexity as it is expanded, many effects can be considered;
6. It is capable to handle zero values.

Further, the JRC report presents a table of recent, 2012 or later, studies focusing on EU-wide index decomposition analyses of energy and emission trends and 7 out of 8 have used LMDI and only one the Laspeyres method.

The avoidance of the residual term and the consistency in aggregation can perhaps be seen as the most advantageous features.

There are variations of the LMDI method, but the variations are minor.

2.3.3 ODYSSEE methodology (ODYSSEE 2017)

ODYSSEE methodology description is according to ODYSSEE (2017). The ODYSSEE decomposition methodology has been developed by Enerdata, with the support of ECN.

In ODYSSEE, technical energy savings are derived from ODEX, an indicator that measures the energy efficiency progress by main sector (industry, transport, households, tertiary and agriculture) and for the whole economy (all final consumers).

For each sector, the index is calculated as a weighted average of sub-sectoral indices of energy efficiency progress; sub-sectors being industrial or service sector branches or end-uses for households or transport modes.

[2]The additive form decomposes the difference between two points in time, while the multiplicative form decomposes the ratio of change with respect to the base year.

The sub-sectoral indices are calculated from variations of unit energy consumption indicators, measured in physical units and selected so as to provide the best “proxy” of energy efficiency progress, from a policy evaluation viewpoint. The fact that indices are used enables to combine different units for a given sector, for instance for households: kWh/appliance, koe/m2, toe/dwelling…

The weight used to get the weighted aggregate is the share of each sub- sector in the total energy consumption of the sectors.

Energy savings by sector in absolute values (ktoe, GWh) are directly calculated from the ODEX. Indeed, ODEX can also be defined as the ratio between the energy consumption at year t (E) and a fictive consumption that would have happened without energy savings (ES).

Therefore, energy savings are equal to

$$ES = Ct_t * (\frac{ODEX_t}{ODEX_{t-1}} - 1)$$

C	Energy consumption
ODEX	Energy Efficiency Index
t	year.

The weighting method has been defined in such a way that the calculation of energy savings is strictly equal to the sum of energy savings by end-use[3], with energy savings obtained by multiplying the variation in unit energy consumption by an indicator of activity. For instance, energy savings for refrigerators are equal to the variation in kWh per refrigerator multiplied by the number of refrigerators.

2.4 Comparison of JRC, IEA and ODYSSEE methodologies

JRC (Economidou 2017) and IEA (2017a) have recently published decomposition results and ODYSSEE (2018a) presents interactively decomposition results on the website. Here, we compare decomposition methodologies of JRC, IEA and ODYSSEE. In Chapter 3 we have a look at the data and relating issues and in Chapter 4 we study the structures used in the sector analyses and the results achieved.

JRC and IEA use the LMDI method, and JRC especially the LMDI-I version of it. ODYSSEE uses its own methodology, whose main feature, reliance on ODEX, has been described earlier. The main features of the three decompositions are described in Table 2.

Chain-linking results year-to-year has advantages according to Economidou (2017): The advantage of chain-linking results is that it captures greater amount of information as it closely follows the path of energy consumption compared to a point to point calculation. It also adjusts to changes in technology or usage patterns when comparing two points separated by a long period of time (Cahill et al. 2010). IEA uses a fixed year approach. The advantage is that an uninterrupted data series is not necessary.

As ODYSSEE decomposition is interactive, the time range can be shortened, if desired.

[3] The energy savings represent “technical savings”, i.e. net of the negative savings due to inefficient operation for industry and freight transport in case of low capacity utilization.

Table 2. Decomposition techniques, time spans and geographical width.

	IEA	JRC	ODYSSEE
Decomposition methodology	LMDI, fixed year	LMDI-I, year-to-year	ODYSSEE own composition, year-to-year
Time range	2000-2014/2015	2005-2015	2000-2014/15
Countries	IEA countries including several EU countries	EU countries	EU countries as well as Norway and Switzerland

The ODYSSEE method is not a clean decomposition. JRC and IEA use decomposition identities that are mathematically unambiguous, that is (C=energy use):

$$C = A \cdot \frac{B}{A} \cdot \frac{C}{B}$$

whereas ODYSSEE decomposition (ODYSSEE 2017) is mainly based on the use of the separately calculated ODYSSEE energy efficiency index, ODEX. This makes the decomposition more like a combination of individual effects and a residual term

$$C = A \cdot \frac{B}{A} \cdot ES \cdot O$$

where ES is the change in energy use according to ODEX and O stands for “Other”. The methodology by which the year to year variations in activity, structure and energy savings effects are calculated appears to be Laspeyresian, so O is the combination of the Laspayres residual term and an ODEX induced deviation from a Laspayresian intensity effect.

As mentioned in Chapter 2.3.3, the ODEX used is a technical index, described as “i.e. net of the negative savings due to inefficient operation”. This is more openly described in (ODYSSEE 2018b):

> This increase in the specific consumption may be due to an inefficient use of the equipment, as it is often observed during economic recession; this is particular true in industry or transport of goods. For instance in industry, in a period of recession, the energy consumption does not decrease proportionally to the activity as the efficiency of most equipment drops, as they are not used at their rated capacity, and, in addition, part of this consumption is independent of the production level. In that case, the technical energy efficiency does not decrease as such, as the equipment is still the same, but it is used less efficiently. It is therefore suggested to separate the technical efficiency from the observed (or apparent) energy efficiency. The apparent energy efficiency index can be replaced by a **technical energy efficiency index, by considering that if the specific consumption for a given sub sector increases its value will be kept constant in the calculation of the technical index.**

This notion has been criticised by (Koreneff & Elväs 2007). And it is criticised again by the author, especially now as ODEX is calculated as a sliding index (ODYSSEE 2018b), on a year to year basis and not to a reference year. If ODEX can only go down, i.e. no negative energy savings are allowed, it gives misinformed results. ODEX is also calculated as a three year average of basic ODEX, but it is unclear if the technicalisation is done before or after the averaging. As can be seen in Table 3, if we assume that unit consumption variation is just random variation, technical ODEX can give a false energy efficiency improvement of 2%

(first calculate average) or 16% (first take the minimum). For the technical ODEX to be an alternative, we should have perfect data, with really deeply disaggregated sub-sector and product structure, perfectly corrected for weather variation etc. And that we do not have. By using technical ODEX, we won't be able to see for example if stricter environmental guidelines decrease energy efficiency nor other changes. For example, because of cost efficiency, appliances and equipment might increase the energy intensity. Neither will we notice sub-sector's structural or behavioural changes or the impact of recession on energy efficiency, severely reducing its imaged information value and thus usability.

Table 3. Behaviour of differently defined ODEX type of indices

Unit consumption	100	102	96	99	104	102	97	102	98	100
ODEX	100,0	102,0	96,0	99,0	104,0	102,0	97,0	102,0	98,0	100,0
ODEX ave t-1,t, t+1	101,0	99,3	99,0	99,7	101,7	101,0	100,3	99,0	100,0	99,0
techn. ODEX	100,0	100,0	94,1	94,1	94,1	92,3	87,8	87,8	84,3	84,3
techn. ODEX of ave ODEX	100,2	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
ave of tech ODEX	100,0	98,0	96,1	94,1	93,5	91,4	89,3	86,6	85,5	84,3

ODYSSEE (2018b) gives the rationale for technical ODEX and uses the graph in Figure 4 as an affirmative of the logic.

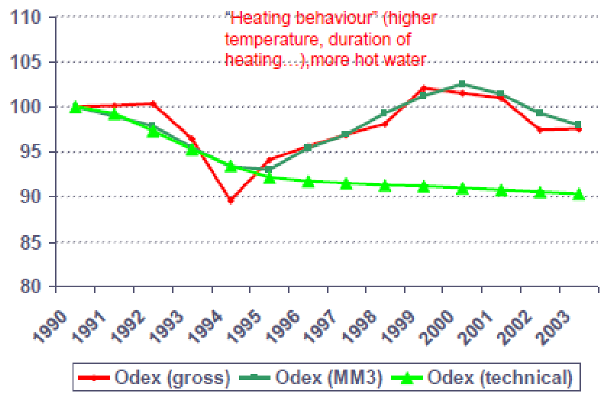


Figure 4. The graph that is purported to give the rationale for using Odex (technical). (ODYSSEE 2018b)

"In some countries, there is a slow down or even a deterioration of energy efficiency progress for heating since the mid-nineties. In a few other countries, there is even an overall increase in the ODEX since 1990. Such changes should not be interpreted as a reduction of energy efficiency, as technical savings have not actually stopped, with all the extra policy measures implemented in the late nineties and the continuous addition of new dwellings that are much more efficient. This situation rather reflects negative behavioural savings, due to higher indoor temperature. This means that the actual energy efficiency progress is under estimated, with the standard calculation of the ODEX, …To separate out the influence of behavioural factors, a technical ODEX is calculated and used to measure the energy efficiency progress…The difference between the technical ODEX and the gross ODEX shows the influence of behavioural factors (see Figure below)."

A better (in author's view) explanation is that the economic recession, which started in the early 90's induced the energy conservation, which was then gradually phased out as household incomes returned to pre-recession levels, and first then we are seeing also energy efficiency improvements. What is also interesting, from 1995 to 1999, when the other ODEX indicators showed an increase, technical ODEX still further decreased.

In addition, as Economidou (2017) refers, Sinton & Levine (1994) showed that as the level of sub-sectoral detail becomes finer, a share of intensity change becomes attributable to structural changes. And structural changes are technical and can go both ways.

In conclusion, methodologically LMDI is far better: No residual term, and the decomposition logic works. The ODYSSEE method is more of a composition method that is based on using sector technical ODEX indices. This might be a workable idea, if ODEX had been normal ODEX instead of the one-directional technical ODEX that is, what more, used on a sliding year to year basis.

3. Data issues

In this Chapter we look at data used and several issues related to it, especially data uncertainties, disaggregation level, discrepancies and other reliability factors and on the boundary issues of final energy consumption.

IEA (2017b) states that important validation criteria include internal consistency, consistency with external data sources, and plausibility (values of indicators need to fall within expected ranges to be meaningful).

3.1 Data used

The data used by JRC (Economidou 2017), IEA (2017b) and ODYSSEE, see Table 4, is improving and getting to be more consistent and congruent, but it is far from being flawless, especially for comparing countries with each other. Weather impact on energy efficiency related data is discussed separately in Chapter 4.2.1. IEA data differs from IEA Energy balances, among others energy consumption in ferrous metals includes energy consumption and losses in transformation for blast furnaces and coke ovens that are accounted under the energy and the transformation sectors in the IEA energy balances (IEA 2017b).

Table 4. Data sources of IEA, JRC and ODYSSEE

	IEA	JRC	ODYSSEE
Timespan	2000-2014/5	2005-2015	2000-2014/15
Countries	IEA MS, including several EU MS	EU28	EU28 and Norway, Serbia
Data source	Data provided state wise, with several EU member states providing ODYSSEE data.	Main data source: Eurostat. From ODYSSEE floor area per dwelling and all transport data.	ODYSSEE database
Missing data	Not all data, especially for 2015 available.	Breakdown of FEC by household end use only for 2010-2015, and badly missing even as such with 10 MS having only 2015 and 4 MS nothing. Road FEC missing from 1/3 of MS, air and water activity likewise	Transportation disaggregate data missing, see analysis of JRC on the left. Household appliance level data missing
Action to correct missing data	IEA Secretariat made estimates for missing data.	Use of similar country data. Assumptions to fill data gaps. Year 2015 data missing for several countries, filled by assumptions.	?

Small changes in intensities may be caused by uncertainty in measurement of energy or activity data, and thus weight should be given to long-term trends, according to IEA (2017b). However, the older the data, the less updated it will be. Energy efficiency statistics are something of a “recent occurrence”, with for example IEA end-use data collecting agreed in 2009, which means that older statistics will probably have less of a base, so from that point of view, having 2005 or 2010 as a starting point could be better. IEA presents results up to 2014 or, if there is sufficient data, 2015. JRC on the other hand fills missing 2015 data with assumptions and presents time series up to 2015, which is actually not that good an idea. A better solution would have been to have 2014 as the last year? IEA and ODYSSEE start year, 2000, was, for example, a very warm year in Finland, which can have its ramifications. JRC start year, 2005, is unfortunate from a Finnish perspective as in that year there was a six weeks long pulp and paper industry shutdown because of a skirmish with the labour union which clearly affected both value added and energy use of the Pulp, Paper & Printing sector. Pulp, paper and printing energy use is nearly 60% of the overall manufacturing industry's, so this aberration is noticeable at all levels of Finnish statistics.

3.2 Data uncertainties, disaggregate level and discrepancies

Data does not always come at the desired disaggregate level, methodological breaks in the time series might exist and methodologies can be in the need of revisions.

The noted problems in the IEA data for EU Member States (MS) by the database documentation (IEA 2017b) would presumably apply to ODYSSEE data as well. Some examples:

- Austria: The data for value added have been revised and show a significant decrease in 2009 for basic metals (ISIC 24).
- Belgium: Some discrepancies between the IEA energy efficiency indicators and the IEA energy balances figures may arise from estimations included to avoid breaks in the time series of natural gas and electricity consumption resulting from a change in the methodology. Work is ongoing to align data and revise historical time series.
- Denmark: Data for energy consumption of water heating is included under space heating.
- France: Energy and activity data include only metropolitan France except for value-added for the industry and services sub-sectors, which includes overseas departments.
- Germany: Data for residential energy consumption have been revised for the years between 2006 and 2015 according to a new methodology.
- Greece: In 2013, taxation on oil products for space heating increased substantially, leading to reduced consumption in the residential sector. According to external sources, the consumption of oil products has been partially replaced by non-commercial solid biofuels not yet reported. This leads to a significant reduction of total space heating consumption in 2013, affecting also the energy intensity of this end use. The space heating intensity shown should, thus, be considered with caution. Work is ongoing to address this issue.
- Hungary: Some breaks in energy consumption data may occur between 2012 and 2013, resulting from an energy consumption survey introduced in 2014. For instance, some energy consumption was reallocated between industry and services sectors. There are also some breaks in the time series of value added data.
- Ireland: Between 2008 and 2009, there is a break in series for certain oil products due to a new methodology being applied to sectoral demand by Sustainable Energy Ireland. This change can also explain breaks between 2006 and 2007.
- Italy: The methodology used to calculate combustible renewables and waste consumption in the residential sector from 2002 was revised, leading to a break in series between 2001 and 2002.
- Luxembourg: Heat consumption in industry is reported only from 2003. Energy consumption of combustible renewables and waste in the wood manufacturing sub-sector is reported only from 2005, leading to a break in the energy intensity time series. Due to confidentiality issues data for energy consumption of chemicals [ISIC 20-21] includes rubber [ISIC 22], whereas regarding value added, rubber [ISIC 22]

are included in the manufacture of non-metallic mineral products [ISIC 23]. Data for value added of basic metals [ISIC 24] and Machinery [ISIC 25-28] are not available.

- Netherlands: The IEA Secretariat estimated some data for energy consumption from heat, oil, and combustible renewables and waste. Data for energy consumption for rubber [ISIC 22] and other manufacturing are included in other sub-sectors.
- Portugal: Some transport energy consumption may be included under industry and services. Results from a survey on energy consumption of solid biofuels in households led to break in series of combustible renewables and wastes between 2009 and 2010. Data on combustible renewables and wastes (solid biofuels) were revised based on a survey for industry, resulting in breaks in the energy consumption data for some sub-sectors between 2011 and 2012, e.g. for non-metallic minerals. Further revisions are expected in the future.
- Spain: Data for electricity consumption for different end-uses have been revised back to 2010 according to a new methodology by the Spanish administration. This causes some breaks between 2009 and 2010.
- Almost all countries had issues with transport sector data, for example missing disaggregated data of energy consumption or activity, methodological or data revisions being in the process. Another difficult issue was household appliance related data.

In conclusion, ODYSSEE has quite well disaggregated and reasonably comprehensive data with data collection and data structure (and energy efficiency indicator) development going on for years, so it has an advantage to Eurostat or IEA data. As IEA (2017b) notes, the IEA end-use data collection agreed in 2009 is still work in progress, with developing quality and coverage across Member countries. Most EU member states use ODYSSEE data for their input to IEA. JRC also uses ODYSSEE data to a certain degree. However, as the list of noted problems above shows, the work is really in the development phase, as many states are just now starting to have a closer look at, for example, transport sector data.

For passenger transport, let’s look at some more detailed data for in ODYSSEE results successful countries, see Table 5. Finnish unit consumption (kWh/tonne-kilometre) of road transport of goods decreased 11% from 2005 to 2006. The reason might be the massive six weeks long pulp and paper industry shutdown in the spring of 2005. As we can note, several changes are really big and perhaps more related to breakpoints in the statics than to real energy efficiency changes. Looking at absolute numbers, there are large differences between the countries. One explanation being that what is included in the values for energy use and service performed might not be congruent data, and not similarly defined for the countries.

Table 5. Transport sector unit consumptions of selected modes for 2015 (exception: Sweden 2013), upper table, and the changes to the unit consumptions from 2005 to 2015 (to 2013 for Sweden), lower table. Data source: ODYSSEE (2018d) database.

2015		Finland	Greece	Italy	Ireland	Portugal	Spain	Sweden	Germany
Cars	TWh	25	30	211	24	34	159	45	416
Cars, passenger	kWh/pkm	0,375	0,302	0,310	0,471	0,407	0,500	0,415	0,439
Bus, passenger	kWh/pkm	0,247	0,118	0,134	0,090	0,354	0,289	0,347	0,145
Trucks and light, goods	kWh/tkm	0,809	1,217	1,210	1,099	0,762	0,509	0,487	0,380
Train, passenger	kWh/pkm	0,056	0,203	0,060	0,243	0,047	0,078	0,063	0,053
Train, goods	kWh/tkm	0,083	0,299	0,088	0,358	0,070	0,114	0,093	0,078
Air, passenger	kWh/pkm	1,079	1,720	0,454		0,688	1,236	0,562	1,979
Water, goods	kWh/tkm	0,670		0,212			0,120	0,099	0,067
2005-2015		Finland	Greece	Italy	Ireland	Portugal	Spain	Sweden	Germany
Cars	TWh	-2 %	-29 %	-18 %	11 %	-19 %	9 %	-12 %	1 %
Cars, passenger	kWh/pkm	-8 %	-38 %	-19 %	-5 %	-16 %	16 %	-12 %	-6 %
Bus, passenger	kWh/pkm	-2 %	-4 %	-1 %	-30 %	31 %	19 %	-13 %	-1 %
Trucks and light, goods	kWh/tkm	37 %	9 %	60 %	52 %	26 %	-18 %	7 %	-3 %
Train, passenger	kWh/pkm	-9 %	63 %	-8 %	4 %	-53 %	-71 %	-8 %	-43 %
Train, goods	kWh/tkm	-9 %	63 %	-8 %	4 %	-53 %	-71 %	-8 %	-43 %
Air, passenger	kWh/pkm	-19 %	-65 %	-29 %		13 %	10 %	-24 %	-1 %
Water, goods	kWh/tkm	-8 %		-38 %			-71 %	-37 %	20 %

3.3 Data boundaries for final energy consumption

Definition of boundaries for some sub-sectors and sectors might be an issue. IEA (2017a) notes that consistency of boundaries and definition between energy and activity data is essential to create meaningful indicators, and to analyse their trends.

CHP energy allocation

The handling of autoproducer CHP should be mentioned. Autoproducer CHP has earlier been a big problem for Finland where industrial CHP is quite common. ODYSSEE used to have both electricity produced and all the fuels used for it as industrial final energy consumption (Koreneff & Elväs 2007). This question has improved since then. Also, the fastest step to statistically reduce energy intensity of an industry site used to be to outsource the CHP unit at the plant site. Koreneff & Elväs suggested that industrial autoproducer electricity production should be included in the energy transformation sector, and this is what energy efficiency databases in IEA (Koreneff et al. 2014) and ODYSSEE (2018b) nowadays do. IEA (IEA 2017b) also adds the fuel used for sold heat to the energy transformation sector, and this is another step forwards. In CHP, the fuel allocation is done in proportion to produced useful electrical and thermal energy, i.e. using the energy method. This means that both heat and power is thought of as produced with the plant’s overall efficiency. The overall efficiency of CHP plants is high, but a bit lower than that of heat-only boilers, so the energy method tends to favour power production and disfavour heat production. Fuel allocation using the benefit allocation method (a.k.a. alternative generation method, see Grauss&Worrell 2011) would be fair and would divide the benefits of CHP equally to power and heat. For example, Statistics Finland produces statistics with both methods. Without a closer study it is hard to say how widespread the use of the benefit allocation method is yet.

Energy statistics

For a deeper analysis of fuel allocation in a CHP unit compared to a heat-only boiler in different circumstances (own, outsourced) and in different statistics (IEA, Statistics Finland), see Koreneff et al. 2014. For example, energy use for the steel production branch differs notably according to source. In Figure 5 energy statistics of IEA and ODYSSEE for the steel sector in Finland are related to Eurostat numbers. Between 2006 and 2007, a data statistics change can be seen in IEA and Eurostat. However, the change has been implemented in ODYSSEE also for older data. Anyway, one can clearly see how the use of different sources give different results.

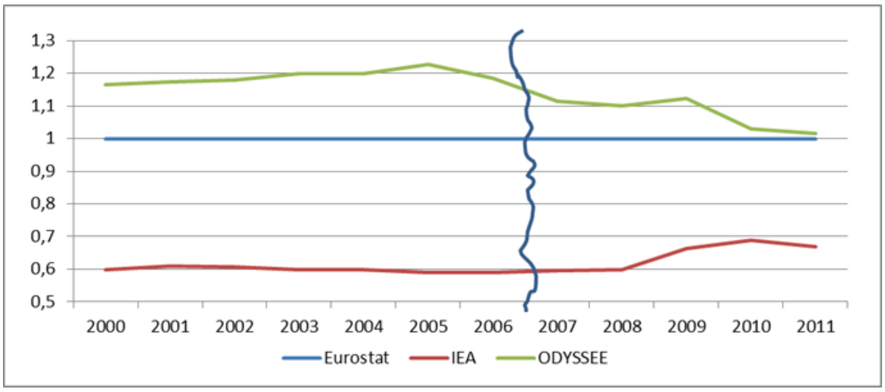


Figure 5. Steel sector energy use in Finland of ODYSSEE and IEA related to Eurostat. (Koreneff et al. 2014, original data sources IEA 2014b, Eurostat 2014, Enerdata 2014)

Direct use of distributed energy sources

Is direct use of onsite non-movable (in contrast to biofuels) renewable energy sources (RES) an energy efficiency measure or not? Technically, on-site “generated” energy is not a final energy consumption[4], as it doesn’t cross the end-user property’s border. However, it is part of the useful energy[5]. Is there a similarity to the use of own wood for heating purposes or biogas production at farmhouses, which hopefully both are included in final energy use. For example, the IEA (2017b) data handling guidelines classifies, e.g. geothermal and solar thermal heat direct use as Other sources. However, IEA (2017a) excludes geothermal heat pumps from geothermal heat, but in it is mentioned that the data for Denmark for combustible renewables and waste in space heating includes the heat contribution of heat pumps. So why is direct use heat pump’s heat treated differently than direct use solar thermal heat? Should direct use of RES really be an energy input, and are some countries treating it as such and some not? In the end, it is also a question of what kind of data is available for the data statistician.

From a heating energy efficiency point of view, ground source heat pump heated houses use more energy than an otherwise similar direct electrical heated house, as the pumps for fluids circulation in the ground is a small, but nevertheless extra burden.

How is PV treated, and especially surplus PV production? Netting of surplus PV production with purchases should of course not be allowed, as it does not improve the energy efficiency of the house. On the other hand, the surplus production should neither be a part in the

[4] Final energy consumption is the energy that crosses the boundaries to the sector’s actors. For example, for electricity, it is the energy of the electricity, not the energy that was used to generate the electricity. Final energy use is a measure of the construction of the house and its energy system.
[5] Useful energy is the energy that the house actually uses, without conversion losses. Only the used heat produced by fuels is taking into account. Useful energy use is a measure of the construction of the house.

household energy use value. As IEA and ODYSSEE especially focus on appliances (incl. heating, hot water, cooking and lighting) and their electricity uses, the question of the origin of the electricity might not be an issue. But in fairness, most appliance usage estimation depends, at least should, on the disaggregation of measured usage. For that reason, and for clarity and comprehensibility, there should be published guidelines concerning direct use of RES.

4. Decomposition - sector results

In this Chapter, we look at the used decomposition structures in the sector analyses and at the results. Decomposition results by IEA are presented as energy savings per sector for individual countries as estimated from graphs in (IEA 2017a). JRC (Economidou 2017) gives indices for activity, structure and intensity, and ODYSSEE´s interactive tool (ODYSSEE 2018a) gives all the effects for each sector. We will mainly look at the results for Finland, Sweden, Germany and Italy. IEA also presents a variety of energy efficiency indicators, but they will not be studied.

IEA (2014) notes that energy intensity as measured by energy consumption per value added or GDP is often used as a proxy for energy efficiency and exclaims that

> “This is a mistake, however, since a given country with a low energy intensity does not necessarily have high efficiency. For instance, a small service-based country with a mild climate would certainly have a much lower intensity than a large industry-based country in a very cold climate, even if energy is more efficiently consumed in this country than in the first. ”

According to IEA (2014), efficiency is a contributing factor in intensity, but many other elements – often more significant – also need to be considered. These include: the structure of the economy (presence of large energy-consuming industries, for instance); the size of the country (higher demand from the transport sector); the climate (higher demand for heating or cooling); and the exchange rate.

It must be noted, that Finland, and Sweden, for that matter, fulfil these circumstances to a dot. Finland is the EU-28 country with the highest share of industry energy consumption of the final energy consumption (ODYSSEE 2018c), around 45%, see Figure 6. Finland is by far the coldest of the EU-28 countries (Eurostat 2018a).

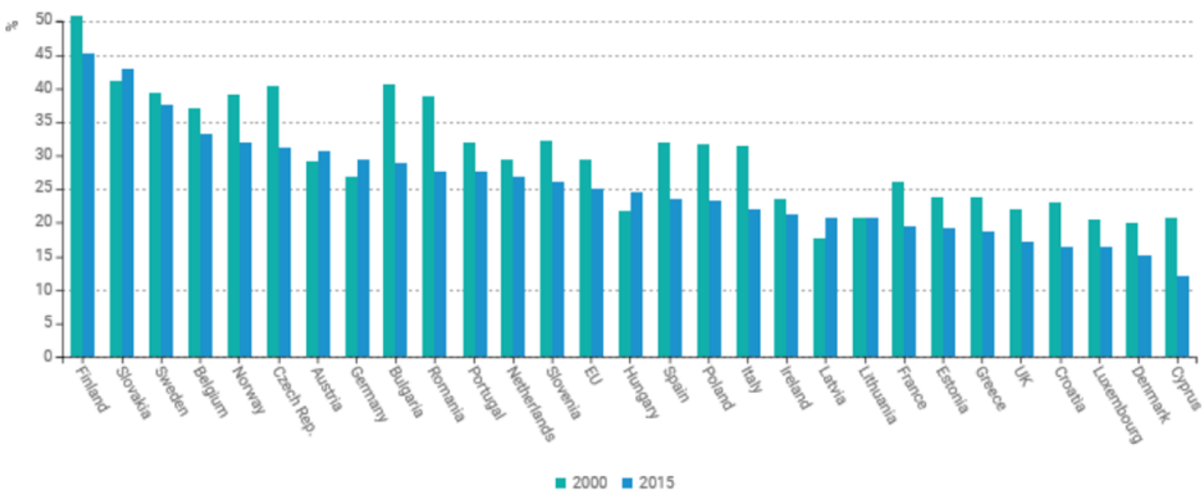


Figure 6. Share of industry in final consumption. (ODYSSEE 2018c)

4.1 Industry, services and agriculture decomposition

The decomposition approaches to industry taken by JRC, IEA and ODYSSEE are presented in Table 6. For lack of sub-sectorial data in the services sector, it has been combined with industry in IEA and JRC studies.

Energy intensity as measured by energy consumption per value added is used as a proxy for energy efficiency in the JRC and IEA decompositions, although IEA notes, see above, that this is a mistake.

ODYSSEE is using production output of steel, cement and paper for the energy intensive branches and production indices for the other industry branches. However, ***ODYSSEE uses paper output as basis for the pulp and paper branch but not pulp output,*** although production of pulp is very energy intensive and the production amounts are by no mean in a 1-to-1 relationship with paper production.

Finland, for example, exports pulp that is used by paper industries elsewhere. In 2014, 27% of the produced pulp was exported and most to Europe. In addition, the energy use for pulp production from recycled fibres is small, 60% to 95% smaller, compared to the production of new fibres. (Pöyry 2016)

Although Finnish recycling of paper and paperboard is a high 66 percent, 95% of paper and paper board production is exported, mostly to Europe (Finnish Forest Industry 2018). Thus, only 6% of the pulp produced in 2014 was based on recycled fibres and the rest from virgin fibres; 27% of all pulp was mechanical pulp, 5% chemi-mechanical pulp and 62% chemical pulp (Pöyry 2016). It is crystal clear that ***Finnish pulp and paper industry cannot be compared to a country where a larger part of the fibres are recycled, or imported*** in the way it is done in ODYSSEE***.*** In addition, with the high aggregation level used, many notable structural changes are seen as energy efficiency changes. For example, newsprint, being less energy intensive than printing and writing paper or soft tissue, is experiencing strongest cutbacks (Pöyry 2016).

Table 6. Industry decomposition in JRC (Economidou 2017), IEA (2017a) and ODYSSEE (2017) studies.

	IEA	JRC	ODYSSEE
Sub-sectors	Food; textiles; wood; paper and printing; chemicals; rubber; non-metallic minerals; basic metals; machinery; transport equipment; furniture/other manufacturing; Agriculture/fishing; Mining; Construction; Services and the commercial sector	"Commercial sector" with 8 subsectors: • Food, Tobacco, Textile, Leather • Wood, Wood Products, Paper, Pulp & Print • Chemical & Petrochemical • Metals & Machinery • Non-Metallic Minerals & other manufacturing • Construction & transport equipment • Services • Agriculture, fishing & forestry	If available: 4 main branches: chemicals, food, textile & leather and equipment goods (machinery and transport equipment); 3 energy intensive branches: steel, cement and pulp & paper 3 residual branches: other primary metals (i.e. primary metals minus steel), other non-metallic minerals (i.e. non-metallic mineral minus cement) and other industries. Mining industry Construction
Activity effect	Value added in USD at price level and purchasing power parities of the year 2010	Gross value added (GVA) at chain linked volumes (2010)	Change in industrial activity (measured with the production index)
Structure effect	Share of value added	GVA_i/GVA	Change in the structure of the industrial by branch (based on production index)
Intensity effect	Energy / value-added	FEC_i/GVA_i	Measured by the ODEX, i.e. calculated from changes in specific energy consumption at branch level. Specific consumption relating the energy consumption to a physical production (case of steel, cement and **paper**) and to industrial production index for the other branches.
Other effects	-	-	"Other": mainly "negative" savings due to inefficient operations in industry.
Comments		Uses the basic decomposition identity $FEC = \sum_i GVA \frac{GVA_i}{GVA} \frac{FEC_i}{GVA_i}$	Production index is not described in (ODYSSEE 2017).

Production index which ODYSSEE is using is described in (ODYSSEE 2018b): "The production index by sub-sector is the most common indicator used to measure the industrial output; it is usually measured in relation to a base year (e.g. index base 100 in 2005 for instance) or in relation to the previous year. … This index usually measures the changes in the volume of physical production: it is calculated from index of change in physical production at a very detailed level (4 to 5 digits) measured with different units (e.g. number of litres of milk processed, of tons of meat produced for the food industry) and aggregated at the branch level (e.g. food) into a production index on the basis of the weight of each sub-branch in the value added of the branch in the base year (2005)."

For value added, IEA uses purchase power parity (to year 2010), which is seen as the preferred method to compare countries instead of just using the exchange rate. As ODYSSEE (2018b) notes, the use of purchasing power parities instead of exchange rates has two consequences: One, it increases the evaluation of GDP and, thus, decreases the intensity of countries with the lowest cost of living, which generally correspond to those with the lowest incomes; conversely, it increases the intensity of the richest countries, and two, it narrows the differences between countries. Purchasing power parity thus influences the ranking of intensities between countries but the trends will remain..

4.1.1 Decomposition results

Decomposition results are presented in Table 7. The results show the effects that the different components have on the energy use. A negative effect of intensity is to be interpreted as energy savings. IEA cumulative lifetime energy savings are estimated from graph, and annual saving for the last year is estimated assuming a linear increase. ODYSSEE results do not include services or agriculture.

Table 7. Industry decomposition results from IEA (2017a), JRC (Economidou 2017) and ODYSSEE (2018a). Negative intensity effect = energy savings.

ktoe		Finland	Sweden	Germany	Italy
IEA	Cumulative energy intensity change 2000-2015	-4600 =>2014; **-700/a**	-26600 =>2014; **-4100/a**	-51000 =>2015; **-7300/a**	N.A.
JRC	FEC 2015	13972	15381	95305	44155
	Activity	508	3210	13264	-1556
	Structure	-1906	-1942	-1113	-1226
	Intensity	**221**	**-3251**	**-8704**	**-11125**
ODYS-SEE	Activity	712	-55	11722	-8362
	Structure	-1803	-319	-6256	1849
	Intensity	**-1425**	**-2548**	**-8240**	**-9115**
	Other	970	2144	5749	1643

In JRC results, the demise of Nokia phones is probably seen as a reduction of value added in Basic metals and machinery and with no practical impact on steel based energy use. This results in a negative structure effect and an increase in intensity - the energy intensive sector's weight (=value added) is reduced and energy per value added increased. The economic catastrophe 2008/2009 is also seen as almost halving the value added of Wood, wood products, paper and printing while the energy consumption is reduced considerable less. The value of pulp and paper, and probably also wood due to reduced domestic construction activity, is low in tow with a decreased global demand.

The energy intensity effect in ´Western Europe was in 2005-2015 around 80-90% except for Ireland (74%), Finland (102%) and Luxembourg (97%) and Mediterranean Malta (101%), Cyprus (106%) and Greece (108%). Eastern European countries showed partially very low intensities, under 40%, and none over 90%

Year 2000 was warm in Finland, but 2015 even warmer. With an overcompensating Heat Degree Day (HDD) compensation, service sector will see an intensity increase from 2000 to 2015 in the JRC and IEA results here.

ODYSSEE data should really be read that energy savings is between the sum of Energy savings and Other and Energy savings. Italy has the largest saving compared to the rest, in the height of 30% of 2015 consumption, and the rest around 3 to 4%, with Finland having the highest achievement.

4.1.2 The good, the bad and the ugly

As IEA notes, for example in the iron and steel sector, a higher level indicator would be energy consumption per unit output of crude steel, while a more detailed level would comprise indicators such as consumption per unit of steel produced by oxygen blower converters or consumption per unit of steel produced by electric arc furnaces, etc. Such process-level indicators are of most interest to energy efficiency analyses. However, their use is still limited due to a general lack of available data, or by the difficulties in allocating energy consumption to specific physical output values, when outputs are heterogeneous in the same establishment. We should note that detailed level examination is only meaningful when a value added can be defined, which is more likely for a product type (e.g. ammonia) than for a process (e.g. dry cement). In any case, indicators based on physical output are always recommended for energy efficiency analyses. (IEA 2014)

JRC and IEA both use value added as the basis. This is not an optimal solution, but for very diverse branches perhaps the only practical solution data wise. However, value added is not a very good measure of the energy efficiency of the industry. Bulk industries (steel, pulp&paper, cement) usually have lower value added and higher energy consumption, but they can nonetheless be very energy efficient. And even if the value added is tied to the money value of a given year, global goods' and energy prices are much more volatile, and they affect the value added of a product. ODYSSEE has done a tremendous work and has focused more on production volumes, with even steel, cement and pulp&paper as own branches.

As for sub-sectors, adding service sector to industry really wreaks havoc on the usability of the results. The service sector is very dominant over industry branches. For example according to JRC sub-sector divisions, services is generally in the ball park of 6 to 15 larger than the next largest sector (in Greece 20x, Luxembourg 18x, Romania and Slovakia x4), so it totally dominates the structure. At the same time, the energy use is at most 2 to 3 times as large (exception: Malta 7 times) as the next largest sub-sector, with three countries (Finland, Sweden and Slovakia) where the energy consumption of services is only the second largest, at roughly half of the largest sub-sector. In addition, much of service sector energy use goes to heating, and services sector space heating is not temperature corrected by IEA (2017) and apparently not by JRC.

In addition, having energy intensive branches together with less intensive industries in the same sub-group/sector diminishes the usability of the results, as structure changes will be hidden. In countries on average in 2014 (IEA 2017a), Machinery as well as Services appear to have an energy intensity around 1 MJ/2010 USD PPP, whereas Basic metals had over 25 MJ/2010 USD PPP, Non-metallic minerals as well as Paper&Printing around 18 MJ/2010 USD PPP and Chemicals around 8 MJ/2010 USD PPP. JRC e.g. groups Machinery with Metals, and Wood and wood products with Paper, Pulp & Print.

Sub-sector composition also plays a role. Whereas the printing sub-sector is providing adequate value added, its unit consumption is low compared to pulp and paper. And even looking at just pulp and paper, there are notable differences in energy use per ton depending on what kind of ton is produced[6]. Mechanical pulp[7] is the most electric energy intensive but chemical pulp the most overall energy intensive. And, of course, use of recycled paper as raw material has a very low energy intensity, only 10% or less than that of chemical pulp. So if Finland shows Paper and printing intensities of 65 MJ/2010 USD PPP, it is not because Finland is so much worse at energy efficiency than for example Denmark with 4 MJ/2010 USD PPP, but the portfolio is different, with a much stronger emphasis on printing in Denmark (and from statistics deducible, some fancy art paper).

The same goes for the steel sector. Steel can be made by oxygen blown converters or electric furnaces, and the electric furnaces are much more energy efficient, as can be seen in this ODYSSEE graph[8], Figure 7 (from Koreneff & Elväs 2007, original from ODYSSEE home pages 6.10.2006). This means a high energy use per tonne steel in the Basic metal sub-sector or even the steel branch is not per se a sign of energy inefficiency. According to World Steel Association (2018), countries having a 99% or greater share of electric arc furnace steel production in EU28 in 2017 include Bulgaria, Croatia, Greece, Luxembourg, Portugal and Slovenia. Of course, the amount of scrap iron used and the type of end product also influence the energy intensities for steel.

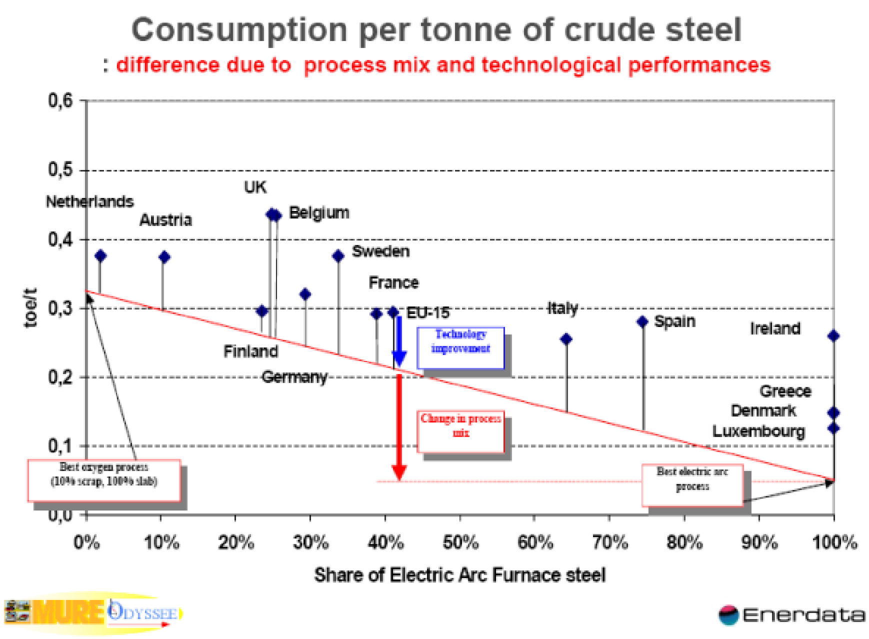
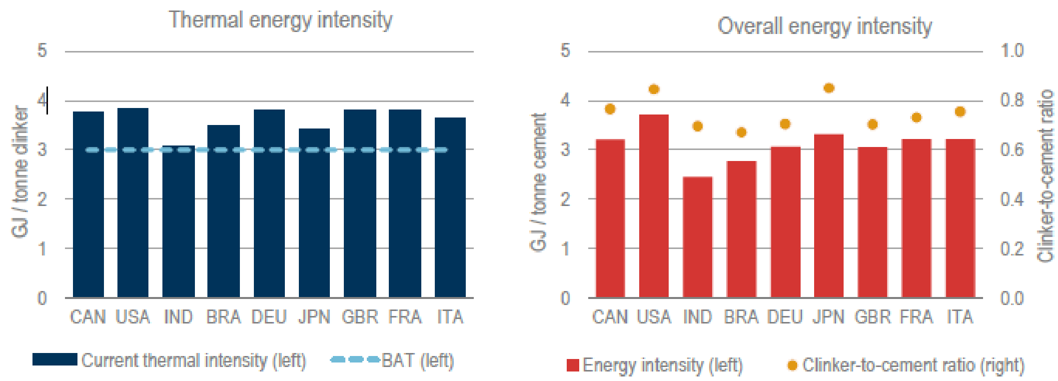


Figure 7. Energy consumption per tonne of crude steel according to manufacturing method. (Koreneff & Elväs 2007, originally from ODYSSEE project website 6.10.2006)

The third sub-sector study is about cement manufacturing – the most significant component of the non-metallic minerals manufacturing sub-sector. Energy is mostly for the production of heat (up to 1 450°C) to make clinker, the major component of cement. The thermal energy

[6] Unit consumptions in Finland 2014 (Pöyry 2016): Newsprint 6.8 GJ/t, coated fine paper 8.0 GJ/t, tissue 11.3 GJ/t, folding boxboard 7.5 GJ/t, ground pulp 6.5 GJ/t, bleached sulphate pulp 16.7 GJ/t, de-inking pulp 1.6 GJ/t and other recycled fibre pulp 0.7 GJ/t.
[7] Mechanical pulp has a much better material efficiency than chemical pulp, so with same amount of wood input, even up to double amount of pulp is produced.
[8] A more recent graph has be published by ODYSSEE, but in it Finnish unit consumption has changed to the worse for some reason. This is more believable.

intensity of cement production is affected by the fuels combusted, the age and type of the kilns etc. Figure 8 shows the current thermal energy intensity in several major economies and the intensity possible using best available technology (BAT). India is closest to BAT due to a combination of new, more efficient, production capacity being recently added and the use of locally sourced lower moisture raw material. Improvements to clinker production are challenging due to the time and capital needed to upgrade kilns. Variation is also seen in the overall energy intensity of cement production. A key factor influencing overall energy intensity is the amount of clinker included in the final cement mix, represented by the clinker-to-cement ratio. In the countries in Figure 8, Brazil has the lowest clinker-to-cement ratio, contributing to its overall energy intensity being 25% lower. The degree to which the clinker-to-cement ratio can be lowered depends on the availability and quality of substitutes, and any regulatory or technical requirements for specific cement applications.



Note: BAT considered as dry-process kiln with pre-calciner and 6 stage cyclone pre-heater at 3 GJ/tonne clinker.
Sources: Adapted from WBCSD Cement Sustainability Initiative (2017), *Global Cement Database on CO_2 and Energy Information* (database), www.wbcsdcement.org/index.php/key-issues/climate-protection/gnr-database.

Figure 8. Energy intensity of cement production 2014. (IEA 2017c)

4.1.3 Separate tertiary and agriculture sectors

ODYSSEE (2017) decomposes tertiary sector separately using value added as activity and a hereto related corresponding structure effect. Weather effect is also calculated. Energy savings are calculated by multiplying the number of employees by the variation of unit consumption per employee by branch, but as with ODEX, if the unit consumption per employee by branch increases, the index is kept constant to measure only technical energy savings. The productivity effect is calculated by difference between the energy consumption variations, the activity effect and energy savings effect.

As earlier ODYSSEE indicator results shows, see Figure 9, unit energy use per employee can decrease (1996-97, 1998-99), but also increase (1997-98, 1999-2004) (Koreneff & Elväs 2007). Service sector tries to do the same work/service with less employees. Grocery stores are more and more box stores, hotels are automated, school employees such as teachers are reduced, nursing staff per patient diminished etc., so intensity as measured per employee should be allowed to rise. Energy per employee is, as seen, not such a good measure for energy efficiency, but rather for employee efficiency. Nevertheless, ODYSSEE uses energy per employee as the energy efficiency indicator. As a lot of service energy is related to the area, square meters could be the main, or at least an additional or alternative activity factor.

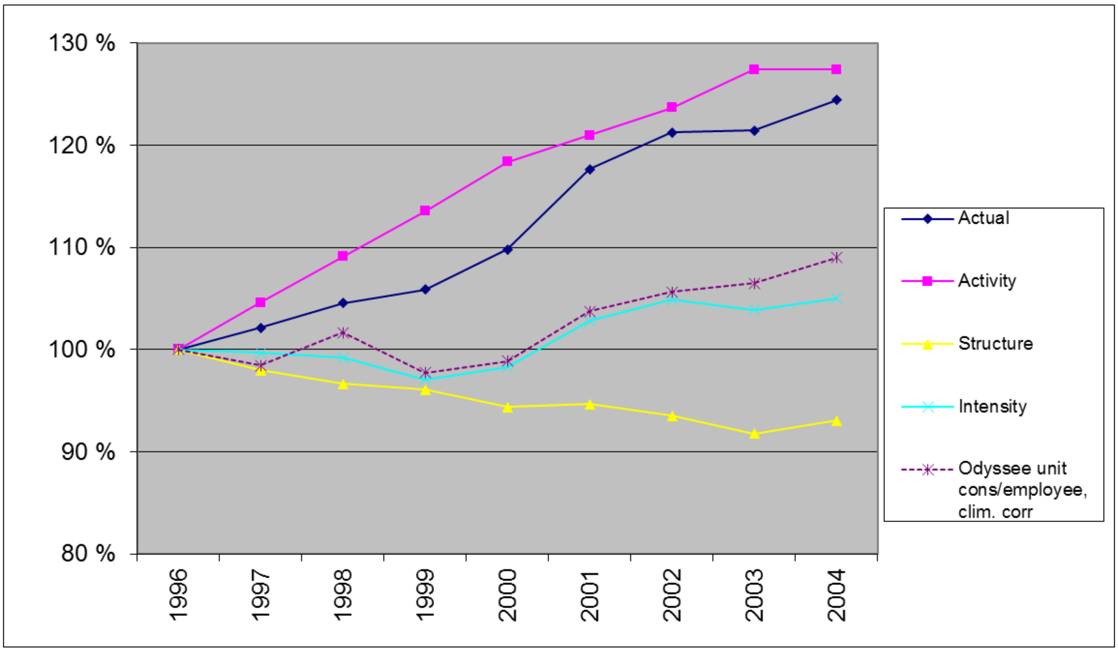


Figure 9. Service sector decomposition results by VTT for Finland 1996-2004 using energy per employees as intensity, along with ODYSSEE weather corrected unit consumption per employee. (Koreneff & Elväs 2007)

ODYSSEE service sector decomposition results are shown in Table 8. The productivity effect is not quite clear, as the explanations in (ODYSSEE 2017) are inadequate. However, if we again combine Energy savings and Other, we see that Sweden has the best result, -62%, with Germany and Finland at -4% to 2%, respectively, and Italy with an energy intensity increase of 18% (compared to 2015).

Year 2000 was warm in Finland, but 2015 even warmer. With an overcompensating Heat Degree Day (HDD) compensation, service sector will see an intensity increase from 2000 to 2015.

Table 8. Service sector decomposition results from ODYSSEE (2018a).

ktoe		Finland	Sweden	Germany	Italy
ODYS-SEE	FEC 2015	2762	3817	30660	16209
	Climate	-56	267	818	239
	Activity	437	2381	5472	668
	Productivity	-100	-1101	-4266	264
	Intensity	-135	-2309	-5212	-467
	Other	195	-66	3966	3322

ODYSSEE (2017) also decomposes the agriculture sector separately using value added as activity. The rest is Other effect, which intrinsically comprises the intensity, structure and weather and other effects. To be honest, this is for energy decomposition such a small sector that it could, and perhaps should, be added to industry and/or service sector, as IEA and JRC have done.

The results show that Finland and Sweden have the largest decreases in Other, somewhere around 30%, while Italy and Germany are at the level of 10%.

4.1.4 In conclusion

As ODYSSEE uses the technical ODEX (and similar in services) to not let energy intensity increase from one year to another, see Chapter 2.4, the results are unusable, or one has to at least combine Energy savings with Other effects. Sub-sector classification and the selected value added based approach of IEA and JRC are clearly inferior to the ODYSSEE approach. The results are not very comparable, even only looking at the directions of the reactions. The decomposition results of the service sector are a tool to help find where to burrow deeper into the data behind, but the results are not what one would call acceptable proof or the objective truth.

4.2 Decomposition of household sector

4.2.1 Decomposition setup for households

The three sources IEA, JRC and ODYSSEE have surprisingly varying setups for households, see Table 9. Both IEA and ODYSSEE have very complicated setups, where data availability and data quality issues might overturn the disaggregate benefits of the more detailed indicators. ODYSSEE, as a more of a composition approach, doesn’t have to have the same kind of clear logic the other approaches do.

Although space cooling is quite common in the Nordic countries, with for example Stockholm having Europe’s largest and Helsinki third largest district cooling networks, it is mostly targeted at the service sector. Some apartment buildings are nevertheless also connected. However, with a high penetration of air-air heat pumps, one might assume that cooling will be quite common in the summer. This will also concern the question of how direct end-use of RES is noted in the energy efficiency statistics.

Table 9. Household decomposition in JRC (Economidou 2017), IEA (2017a) and ODYSSEE (2017) studies.

IEA	**Activity**	**Structure**	**Efficiency effect**
Space heating	Population	Floor area per population	Space heating energy per floor area
Water heating	Population	Occupied dwellings per population	Water heating energy per occupied dwellings
Cooking	Population	Occupied dwellings per population	Cooking energy per occupied dwellings
Space cooling	Population	Floor area per population	Space cooling energy per floor area
Lighting	Population	Floor area per population	Lighting energy per floor area
Appliances	Population	Appliance stock per population	Appliances energy per appliance stock
Comments: Six sub-sectors		Dwellings only primary residences, and floor area of these	Space heating adjusted for climate variation using heating and cooling days
JRC	**Activity**	**Weather**	**Intensity**
Heating	Total floor area (TFA)	HDD/HDD_{ref}	FEC_{heat}/TFA
All other use	Gross Disposable Income (GDI)		FEC_{other}/GDI
ODYSSEE	**Activity**	**Structure**	**Energy savings/ODEX**
Heating	Change in number of dwellings	Climatic difference, Change in floor area per dwelling, Change in central heating	Unit consumption per m2 at normal climate
Water heating	Change in number of dwellings		Unit consumption per dwelling with water heating
Cooking	Change in number of dwellings		Unit consumption per dwelling
Large electrical appliances	Change in number of dwellings	More appliances per dwelling,	Specific electricity consumption, in KWh/year/appliance

“The increasing number of equipment per households is due on one hand to the increasing number of electrical appliances (ICT, small electrical appliances, air conditioning in Southern countries), larger homes which requires more energy and central heating which requires around 25% more energy compared to single room heating. The increasing number of electrical appliances is approximate with the electricity consumption of large appliance (refrigerators, freezers, TV, washing machine, dish washers) per dwelling in relation with the overall index for electrical appliances (based on the evolution of the electricity consumption per appliances weighted by their energy share). For small appliances and lighting, we take into consideration the energy consumption per dwelling. The ‘central heating’ effect is calculated as a ratio between the unit consumption per m^2 (with climatic corrections) and the unit consumption per equivalent dwelling (with climatic corrections). The unit consumption per equivalent dwelling considers the number of dwellings with central heating (a correction factor of 0.75 is applied to take into account that a dwelling with room heating consumes 25% less than a dwelling with central heating).” (ODYSSEE 2018b)

IEA (2017a) calculates heating degree days (HDD) as the difference between T_{base} and T_k, where T_{base} is the base temperature below which heating systems are turned on and T_k is the average temperature of day k. The difference for all days where $T_{base} > T_k$ is added up. The base day in the UK is typically 15.5 °C and in USA 18 °C, but is should be carefully determined to suit the region. The reference period for HDD_{ref} is from 2000 to latest year. (IEA 2017a)

JRC (Economidou 2017) uses JCR HDD data for heating degree days. The average HDD for 1990-2015 is used as reference. As noted in the Chapter of data, disaggregate heating demand data is available at best only for years 2010 onwards. However, for example Finland and Sweden and eight other countries have data only for 2015, so the heating energy at normal climate for that year is used for all years, which will have a dampening effect on the usability of the results. The activity effect (total floor area) will directly be mirrored to the adverse intensity effect. Four countries have no breakdown of space heating from other energies, and for them assumptions based on neighbouring or similar countries have been used. ***As space heating is the main household energy usage in most countries, it is quite questionable to present country comparison results based on such flimsy data as JRC does.***

Finnish heating demand (according to ODYSSEE database) and to normal climate adjusted heating demand as given by ODYSSEE (Heating(ref,ODY)) and as calculated using JRC Heating degree days (also shown with the JRC reference heating degree days) is shown in Figure 10. The JRC HDD's are much higher than the HDD's used in ODYSSEE, and a flexibility factor of 1 is used for the temperature adjustments with HDD/HDD_{ref}. ODYSSEE uses a factor of 0.9. As country comparisons will become more general, it could be a good idea to update ODYSSEE HDD's to match Eurostat.

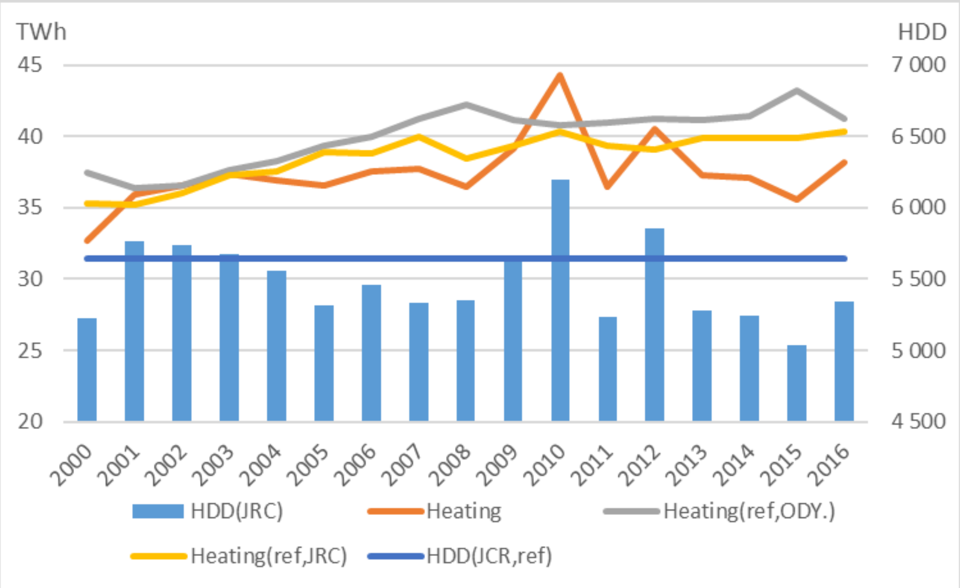


Figure 10. Heating demand in Finland 2000- 2016 and adjusted to normal climate.

JRC's heating degree days are used by Eurostat. There is a good description available at Eurostat (2018a):

> The calculation of HDD relies on the base temperature, defined as the lowest daily mean air temperature not leading to indoor heating. The value of the base temperature depends in principle on several factors associated with the building

and the surrounding environment. By using a general climatological approach, the base temperature is set to a constant value of 15°C in the HDD calculation. **If $T_m \leq 15°C$ Then [HDD = $\sum_i(18°C - T^i_m)$] Else [HDD = 0]** where T^i_m is the mean air temperature of day i.

We see that HDD is calculated differently in Eurostat than by IEA, who uses the base value both for threshold and for HDD indoor temperature. In Eurostat (and by assumption, JRC) the base temperature (15 °C) is not the same as the HDD indoor temperature, 18 °C[9].

Published Eurostat HDD is an arithmetic national average of the measurements of various meteorological stations existing in the country. The reference HDD in Eurostat is based on 25 years, 1980-2004. (Odyssee 2018b)

ODYSSEE has own HDD's. Whereas Eurostat HDD has 18 °C as reference indoor temperature, to use 18 °C is only the suggestion of ODYSSEE management. Finland for example uses 17 °C as indoor temperature value for the ODYSSEE HDD. The heating period for the ODYSSEE HDD's can depend on base temperature as for Finland (12 °C in autumn and 10 °C in spring[10]). The Finnish HDD in ODYSSEE are calculated as a population weighted average of the temperatures of the individual meteorological stations, but it is not known if this recommended way is used by other countries for their input. (Gynther et al. 2010)

The heating period for the ODYSSEE HDD's can be estimated in other ways, e.g. October to April. Some countries in ODYSSEE have shortened the reference period for HDD to start in 1990 and/or are using a moving average. (Odyssee 2018b).

If we want to compare heating energies in Europe it is best done compared to European reference climate. In that case, it would be smashing if all national HDD's followed the same definition. On the other hand, for a nation's internal use, the national HDD should be defined as to give the most stable space heating demand at normal climate. ***We would need two sets of HDD's, one for corrections to national normal climate and one for adjustment to European climate.***

Whereas the energy for heating (space and domestic hot water) is easier to measure, the disaggregation between these two is usually modelled. If we use a constant share, for example allocate 30% to domestic hot water, the hot water time series will vary in step with annual climate.

The problems with hot water disaggregation are presumably peanuts compared to the disaggregation of household electricity to different appliances on an annual basis. A bit different but still reasonable assessment might give a very different comparison to other nations in the decompositions. Should we really go to this disaggregate data level, if we do not have reasonably good statistics?

JRC uses household income as an activity factor for other household energy use than heating. It is not such an obvious choice, especially as more income might lead to more energy efficient investments and sooner than otherwise. It is surely an explaining factor in less wealthier households, but almost all households have a TV and a refrigerator. The impact might be greater on heating, with increased indoor temperatures, longer heating

[9] It is assumed that internal heat sources such as persons and electrical apparatus and external heat sources such as solar radiation will cover the temperature difference between HDD indoor temperature (here 18 °C) and the real indoor temperature.
[10] UK and Ireland usually use a higher threshold/base value, 15.5 °C, but it is not known if it is used in ODYSSEE (Gynther et al. 2010). IEA, as earlier noted, uses this threshold/base values as indoor temperature for UK in HDD calculation.

times, but also via energy efficiency investments, as already mentioned. For example, household income is not the primarily preferred reference by IEA (2014)

IEA 2017c notes that space heating intensity (energy use per floor area) has improved by 45% in Germany and 36% in France since 2000. 45% is not achieved in 15 years by putting a bit more insulation on some houses and switching to condensing gas boilers, so it would be very interesting to heart what is behind this marvellous number. Improvements in Eastern part of Germany?

4.2.2 Decomposition results

Decomposition results for households are presented in Table 10. The results show the effects that the different components have on the energy use. A negative effect of intensity is to be interpreted as energy savings. IEA cumulative energy savings over the whole period are estimated from graph, and from this annual saving at the end is estimated assuming a linear increase.

Table 10. Household decomposition results from IEA (2017a), JRC (Economidou 2017) and ODYSSEE (2018a). Negative intensity change = energy savings.

ktoe		**Finland**	**Sweden**	**Germany**	**Italy**
IEA	Cumulative energy intensity change 2000-2015	-2000 =>2014; **-300/a**	-16000 =>2014; **-2500/a**	-189000 =>2015; **-27000/a**	N.A.
JRC	FEC 2015	4898	7197	53171	32495
	Activity	1072	1372	8707	2261
	Weather	-176	-174	-3054	-4456
	Intensity	**-1018**	**-1307**	**-15980**	**768**
ODYS-SEE	FEC 2015	4757	7209	54974	32495
	Climate	-243	647	2058	773
	More dwellings	768	430	4899	4439
	More appl/dw	0	0	979	5538
	Larger homes	320	1730	5870	-962
	Intensity	**-471**	**-4365**	**-23310**	**-3546**
	Other	19	985	2755	-1329

ODYSSEE results show high energy savings (Energy savings and Other) compared to FEC 2015, for Sweden 47%, for Germany 37%, for Italy 15% and only 10% for Finland. This might also be the technical ODEX effect. Looking only at Energy savings and comparing to year 2000 consumption, Sweden has saved over 56%. This number is sooo hard to believe, unless heat pump heat is not calculated as FEC for Sweden. The composition structure is so complicated and the information given bewildering that it is hard to say anything definite. The lack of appliances data leaves the effect at null, which affects the Other effect.

JRC results are terribly lacking as heating data exists just for some of the last years, which hides all the advances made in heating. But is that why Finland fares relatively better compared to the others, or is it the short time period?

4.2.3 Heating of buildings -what is energy efficiency and what not?

What is then energy efficiency? As already noted in Chapter 2.1, energy efficiency is not that easily defined. According to IEA (2014), it is generally thought that an increase in energy efficiency is when either energy inputs are reduced for a given level of service, or there are increased or enhanced services for a given amount of energy inputs. This means that much depends on the definition of service. Is the service to heat the house, so that by turning down indoor temperature settings one performs an act of energy efficiency? Or is the service to keep the house at a desired comfortable temperature, where lowering it would be conserving energy, but not an energy efficiency improvement?

Heating behaviours are surprisingly different in different countries. For example in England and Ireland heating is usually only on when someone is at home. It is switched off when the last one departs, however, some base temperature such as 15 °C might be kept. In the Nordic countries a constant indoor temperature is commonly kept even though no one is at home. Is the temporary cutting of the heating an energy efficiency act?

The answer is probably a mix of these alternatives, so that a guideline indoor temperature would work as the turning point of the service, where one goes from improving energy efficiency to conserving energy. And not only for heating, the same could be used for cooling.

Is installing central heating in a room heated house an act of anti-energy efficiency? Most would see it as no, but as an allowed improvement of the living comfort. There are a mass of smart grid projects, for example RealValue[11], which target harnessing end-user heating system with smartness, for control and for power system flexibility. As dwellings nowadays and in the future will be smarter and occupants will be able to control temperatures and comforts on a room level and in time in such a way that their experience of the service, however measured, gets full points. While all are away, heating can be minimized and room temperatures drop, but are raised in time before someone comes home. During the night, temperatures can be lowered according to user preferences, and settings can of course easily be overridden if the need arises. The service would be the same, but more energy and cost efficient. So, room wise heating is just the manual version of future’s target. Even though “room heating” specifically defines heating systems that are not connected, the notion itself will become broader in the future such as described above and might lead to misinterpretations and the definition used should be stated in each report and database.

Is there a way to agree on minimum and maximum temperatures at home within we are “allowed” to try to stay with a good conscience? In Finland this could be around 22 °C.

Is there a barrier in energy efficiency that should not be broken? The house should not be too cold so as to avoid dampness, moisture, mould and other unwanted indoor air problems. Air ventilation has to at least follow a minimum flow for the indoor air to be healthy enough. In our strive for more and more energy savings, let’s not forget who is the master and who the servant.

[11] EU H2020 project, ended 2018, see http://www.realvalueproject.com/

4.3 Decomposition of transport sector

4.3.1 Decomposition setups

The decomposition approaches to transport taken by JRC, IEA and ODYSSEE are presented in Table 11.

Table 11. Transport sector decomposition in JRC (Economidou 2017), IEA (2017a) and ODYSSEE (2017) studies.

IEA	**Activity**	**Structure**	**Efficiency effect**
Passenger car; bus; rail; domestic aviation	Passenger kilometre	Share of passenger-kilometres by mode	Energy per passenger-kilometre
Freight road transport; rail; domestic shipping	Tonne kilometre	Share of tonne-kilometres by mode	Energy / tonne-kilometre
JRC	**Activity**	**Modal shift**	**Intensity**
Passenger transport Road Rail Air	Passenger kilometres (PKM)	PKM_i/PKM	FEC_i/PKM_i
Freight transport Road Rail Water	Tonne kilometres (TKM)	TKM_i/TKM	FEC_i/TKM_i
ODYSSEE	**Activity**	**Structure**	**Energy savings**
Passenger transport Car Bus Rail	Passenger kilometres (PKM)	PKM_i/PKM	FEC_i/PKM_i
Freight transport Truck Rail Water	Tonne kilometres (TKM)	TKM_i/TKM	FEC_i/TKM_i

ODYSSEE does not follow the Laspeyres mode of keeping the other effects at t_0 status and only letting one effect have the value at t_1. The energy saving is calculated by multiplying the change in unit consumption per passenger or good kilometre by mode with new passenger or good kilometre. The modal is calculated at an aggregate level, corresponding to difference between the sum of savings of each mode for passenger and goods respectively and the aggregate savings calculated directly for passenger or goods as a whole. In addition, the Other effect is also in use.

4.3.2 Decomposition results

Decomposition results are presented in Table 12 for passenger transport and in Table 13 for freight transport. The results show the effects that the different components have on the energy use. A negative effect of intensity is to be interpreted as energy savings. IEA numbers are estimated from graph, and annual saving is estimated assuming a linear increase.

Table 12. Passenger transport decomposition results from IEA (2017a), JRC (Economidou 2017) and ODYSSEE (2018a). Negative intensity change = energy savings.

ktoe		Finland	Sweden	Germany	Italy
IEA	Cumulative energy intensity change 2000-2015	-1400 =>2014; **-220/a**	-2400 =>2014; **-370/a**	-4800 =>2015; **-680/a**	N.A.
JRC	FEC 2015	3106	5465	46252	25013
	Activity	187	367	3490	571
	Structure	-195	-103	-397	823
	Intensity	**150**	**-483**	**-2470**	**-4985**
ODYS-SEE	FEC 2015	3054	5282	45645	23465
	Activity	597	801	7917	1621
	Modal shift	16	-119	108	-442
	Intensity	**-228**	**-875**	**-7260**	**-5617**
	Other	-12	60	49	-117

Table 13. Freight transport decomposition results from IEA (2017a), JRC (Economidou 2017) and ODYSSEE (2018a). Negative intensity change = energy savings.

ktoe		Finland	Sweden	Germany	Italy
IEA	Cumulative energy intensity change 2000-2015	2600 =>2014; **400/a**	5200 =>2014; **800/a**	-49000 =>2015; **-7000/a**	N.A.
JRC	FEC 2015	3106	5465	46252	25013
	Activity	187	367	3490	571
	Structure	-195	-103	-397	823
	Intensity	**150**	**-483**	**-2470**	**-4985**
ODYS-SEE	FEC 2015	1692	2361	16159	13919
	Activity	-408	129	3872	-3299
	Modal shift	-32	58	600	-1459
	Intensity	**-3**	**-163**	**-452**6	**-996**
	Other	555	257	831	7208

The results from the different studies are quite different. For passenger transport, the improvements in the Nordic countries are smaller in ODYSSEE but larger in IEA. In freight transport, intensities (for ODYSSEE Energy savings and Other) are in many cases increasing, except in Germany. ODYSSEE's different handling of intensity and modal shifts might be the reason that the modal shifts in Finland and Sweden are so small.

The data is also not uniform. For example, Spain's train transports use roughly only 1/3 of the energy beginning 2013, with unchanged activity levels, and water transport 40% less. Electrification does not seem to be the answer to this mystery, perhaps privatisation and statistics gathering changed? Portugal has a statistics breakpoint 2011/2012: consumption of cars drop by 24% while passenger-km drop by only 1%; motorcycles consumption has a drop of 68%. Overall, there is a lot of swaying in the statistics in early 2010's, and perhaps not only because of the recession, which will affect an ODEX type of "only positive changes" indicator's results. Passenger consumption fell in 2011/2012 in Italy 5%, Greece 15%, Portugal 23% and Spain 7%.

In conclusion, with similar data and setups, the decomposition result differences of IIEA, JRC and ODYSSEE are astonishing. The differences stem from using different methodology and probably from how missing time series and values are handled. The large differences in the results are a good example of the volatile nature -and partly unreliability- of energy efficiency analyses. To use one statistic as "the Truth" is not to be recommended.

4.4 Summary and comparison of results

To get a better apprehension of the comparisons, we have summed the results from ODYSSE and JRC for some Western European countries, as they might experience similar developments, in Table 14. Eastern European countries are on another path, more comparable to each other. In the table, ODYSSEE percentages are calculated as ODYSSEE energy savings per energy consumption 2005, and JRC as 100% − Energy intensity-%, so the levels are not an exact match.

Table 14. Sector energy savings 2005-2015 from ODYSSEE (2018a) and JRC (2017)

	Households		Industry	Services	Commer-cial	Transport			
						Passenger		Goods	
	ODYSSEE	JRC	ODYSSEE	ODYSSEE	JRC	ODYSSEE	JCR	ODYSSEE	JCR
AT	13 %	7 %	10 %	23 %	16 %	4 %	-1 %	8 %	10 %
DK	18 %	23 %	19 %	4 %	22 %	7 %	5 %	6 %	11 %
CY	24 %	20 %	29 %	39 %	-6 %	10 %	-11 %	0 %	-43 %
FI	**5 %**	**20 %**	**6 %**	**4 %**	**-2 %**	**4 %**	**-5 %**	**0 %**	**-26 %**
FR	18 %	21 %	7 %	9 %	13 %	5 %	6 %	4 %	8 %
BE	22 %	37 %	14 %	0 %	7 %	9 %	2 %	16 %	-10 %
EL	20 %	15 %	11 %	8 %	-8 %	26 %	33 %	0 %	-8 %
DE	23 %	25 %	9 %	7 %	9 %	10 %	5 %	13 %	6 %
IT	6 %	-2 %	15 %	1 %	19 %	13 %	17 %	4 %	-37 %
IE	37 %	37 %	20 %	23 %	26 %	8 %	29 %	2 %	-159 %
LU	13 %	43 %	1 %	36 %	3 %	3 %	13 %	0 %	-60 %
NL	30 %	28 %	20 %	14 %	19 %	9 %	-1 %	0 %	-1 %
PT	28 %	27 %	17 %	23 %	16 %	15 %	-9 %	8 %	3 %
ES	27 %	11 %	15 %	23 %	19 %	11 %	-20 %	12 %	19 %
SE	27 %	18 %	5 %	41 %	19 %	11 %	8 %	5 %	-10 %
UK	34 %	35 %	16 %	26 %	19 %	11 %	-3 %	0 %	-3 %

The results differ more or less in all sectors, but especially in transport, they have often a different sign. Results for transport sector should be quite similar, as both approaches use the same data. Not to say, possible different strategies to missing data might also have a large impact, but we have no knowledge of the strategy used by ODYSSEE. Anyway, as ODYSSEE does not allow a negative energy saving progress, and added to that, uses a sliding year-to-year approach, the results are quite different. ODYSSEE's approach is more like a composition approach, where different effects are gathered together and the residual is called "Other effect", which often times is large. The ODYSSEE data that JRC used in their study is not necessarily the data that is today available and was the basic for ODYSSEE decompositions, but that should be a minor issue at best. ODYSSEE is to be complimented that data updates to history data are readily made if and when the need arises. JRC made some assumptions for part of the data related to Table 14 (freight road: BE and LU; freight water: LU, UK, DK, EL, IT, PT and FI; passenger road: BE and LU; passenger air; BE, IE, CY, LU and NL), which can also explain some parts of the differences.

All decomposition approaches have weaknesses. One weakness is to use an unsuitable/less suitable indicator or actually denominator for energy efficiency purposes (e.g. money: JRC/Industry&households, IEA/Industry; employees: ODYSSEE/services). The second is to use too aggregated data when more disaggregate data is not available for all parts (e.g. combining industry with service sector: IEA, JRC; only paper tons for pulp and paper energy: ODYSSEE). A third weakness is to simulate, replace or approximate missing time series altogether or just missing values (JRC, IEA; ODYSSEE?), not cutting the time period short with one year as data is missing from many or even most countries (IEA, JRC) or select data sources that do not span the time interval at all (Eurostat/space heating data: JCR). And one source is to use “technical indices” that do not take into account energy saving and conservation behaviour in their definitions, leading to meaningless nonsense indicators (technical ODEX: ODYSSEE).

5. ODYSSEE Scoreboard

ODYSSEE Scoreboard is a country ranking scoreboard, where countries get points as to how well they are doing on the energy efficiency front and are then compared to other countries (EU-28 and Norway and Switzerland).

As we already saw with the decomposition results, there is no single truth and even using same data, the results might differ substantially. How trustworthy is the scoreboard?

IEA (2014) notes that energy intensity is often used as a proxy for energy efficiency and exclaims that it is a mistake, as for instance, a small service-based country with a mild climate would certainly have a much lower intensity than a large industry-based country in a very cold climate, even if energy is more efficiently consumed in this country than in the first.

According to IEA (2014), efficiency is a contributing factor in intensity, but many other elements – often more significant – also need to be considered. These include: the structure of the economy (presence of large energy-consuming industries, for instance); the size of the country (higher demand from the transport sector); the climate (higher demand for heating or cooling); and the exchange rate.

It must be noted, that Finland, and Sweden, for that matter, fulfil these circumstances to a dot. Finland is the EU-28 country with the highest share of industry energy consumption of the final energy consumption (ODYSSEE 2018c), around 45%, see Figure 11. Finland is by far the coldest EU-28 country. How well will the scoreboards succeed in taking these points into consideration?

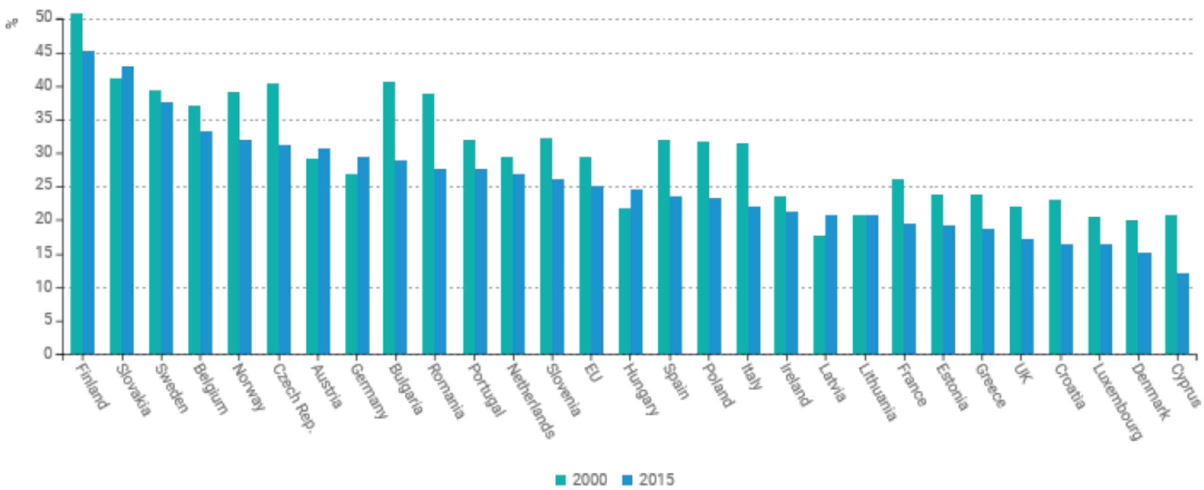


Figure 11. Share of industry in final consumption.(ODYSSEE 2018c)

5.1 Basic principle of ODYSSEE Scoreboard

According to ODYSSEE (2018e), the Scoreboard methodology compares countries in a normalized fashion, where for each indicator a country's distance to the worst is set in comparison to the distance of the best to the worst country. Thus, normalized scores get between 0 (for the worst) and 1 (for the best).

The score by sector is based on scores calculated for selected indicators representative of end-uses in buildings or modes in transport. For industry the score is directly based on an aggregate indicator that already accounts for the energy efficiency characteristics of the various industrial branches.

Three different scores are calculated for each indicator:

1. the level of the indicator. It is calculated as a moving average of the last three years indicator values to smoothen yearly variations.

2. the trend indicator, calculated as variation 2000-2015.

3. the third combines level and trend using equal weights.

The score by sector is calculated as a weighted score of each indicator. The weights correspond to the average shares over the last 3 years of each end-use or transport mode in the sector consumption.

A global score is also calculated. It results from the sectoral scores weighted by the share of each sector, based on the average share over the last 3 years, in the total final energy consumption.

The global and sectoral scores are finally normalized to 1, with 1 corresponding to the highest score value. This normalisation has been added to make the indicators scores consistent with the ODYSSEE-MURE policy scores in the composite score.

ODYSSEE Scoreboard result data used in this Chapter are acquired from ODYSSEE (2018f).

5.1.1 Data used for the indicators

It is a nuisance that the data used is not described in the ODYSSEE Scoreboard methodology (ODYSSEE 2018e). For example, air passenger efficiency includes international flights, which is a choice and is OK, but it could be mentioned, and the same goes for all other indicators.

Most of all, there is no description of how missing data value is managed. E.g. in the case of car efficiencies, when:

1. altogether not measured: will the country be given the value of a similar country, as seems to be the case of Malta/cars efficiency, who receives the values of Cyprus? As Cyprus is also the worst case, is that really fair to Malta? Or if it received the best values, would that be fair to other countries?

2. years are missing in the beginning: the trend will be calculated from the first year with data? OK, and as it is presented as % change divided by number of years, seems fair. However, the starting, and the end, point will affect the trend, to the advantage or disadvantage. One year’s difference can make a whole lot of a difference, as for example data normalisation according to temperature is a not so easy task.

3. last years are missing? Do we assume some kind of efficiency trend, or just use the last measured year as level reference? As Finland only had data for 2000, 7.0, and the indicator scoreboard gave the level as 6.7 and a trend of -0.3%, is the value (6.7) taken from a neighbouring country or is the trend taken, and if so, from where?

4. as the scoreboard actually uses the average of last three years for the level, if one year is missing, is it using the average of the other two, and if two years are missing, the only year there? What if the last three years are missing, but data for the year before that exists? Will it be used as such, trend corrected or not used at all?

It is difficult to analyse the scoreboard, as the data in ODYSSEE database is different from what has been used for the indicators in the scoreboard, for example,

- "Average specific consumption (l/100 km) of cars". See example above of case of missing data, but in addition: according to the database, UK´s efficiency 2015 is 7.6 l/100 km, one of the worst values. In the scoreboard indicator numbers, UK has the best value, 5.9 l/100 km. Use of another source, copy-paste-error,…?

- Unit consumption of road transport of goods (toe/tkm) differs, for example Finland has a slightly larger value than in the database, while Portugal's database value is 1/3 larger than the scoreboard value.

Of course, these differences could have a structural reason behind them, but no such reason was found despite extensive trying and testing.

If data is seen as important enough to be used in the scoreboard, e.g. the number of centrally heated dwellings or the heating degree days of the European average climate, it actually should be made available in the database. Share of dwellings with solar water heater is not in the database, but is found separately in the ODYSSEE toolbox.

5.1.2 Points and weights

As data reliability is what it is, the extreme values might be quite far from the median. In some cases, perhaps the data reliability behind these values is not the best. This will influence the overall score points a country gets, but it might also affect the internal ranking of the other countries:

> Let's presume that all countries but one are around 10-11, but one is ahead at 20. This gives the one country ahead 1 point and all the rest somewhere near 0, which is not a good solution. Let's assume a country is in the middle of the rest, at 10.5. Further, let's assume that this indicator has the weight 60% for half the countries and 30% for the rest. The country with a high weight will have summed up just 0.03 aggregation points, and the countries with the low weight 0.015.
>
> If the second indicator is normally distributed, if a country is in the middle, it will get 0.5 points. A country with a high weight for the previous indicator, will now get 0.4x0.5=0.2 and altogether 0.03+0.2= 0.23 points, and a country with a low weight for the previous indicator will now get 0.7x0.5=0.35 weighted points for this indicator and altogether 0.365. The overall ranking will be seriously distorted for two countries of identical energy efficiency.

To give points according to placement in country ranking of an indicator is as bad an evaluator. Even if several countries are very close to each other, their point difference might still be very large.

One solution would be allow several countries to reach full and null points, giving for example the value 1 to the 3 highest performers, and 0 to the 3 lowest performers, and scale the rest in between (low 3rd to high 3rd), as was presumably done earlier and still remains in the spider web graphics on the ODYSSEE site. Another way would be to dismiss country performances that are not as believable as one would want, but this is politically not an easy task. Perhaps data outliers should be scrutinized more thoroughly and even dismissed, if they are found to be less plausible.

5.1.3 Trend

Trend, assuming it is calculated as relative change, has the weakness that if one starts off from an energy squandering position, it is much easier to make large changes, and still not come into the vicinity of the level that another one had at the beginning. No to say that anyone who makes large changes should not be rewarded, but the trend should also somehow be connected to the level, so that the state-of-art country can also be successful, even if its improvement is not as flashy in relative terms.

For example, Finland had the best level of car efficiency in 2000, 7.0 l/100 km (from ODYSSEE (2018d) database), and reduced it to 6.7 l/100 km in 2015 (from Scoreboard indicator numbers, not in database), a reduction of 0.3% (which is also the ODYSSEE scoreboard trend value) for each year 2000 to 2015. Sweden had in 2000 8.8 l/100 km and in 2015 7.0 l/100 km, which is a reduction of 1.4% for each year between 2000 and 2015 (although ODYSSEE scoreboard gives the trend as -1.6%). If we could tie the trend to level in the beginning, it might not be such a bad idea, e.g. by multiplying trend score point with (1 + level score points at year 2000).

Trend as tied to year 2000 data has the weakness that year 2000 data is perhaps not the soundest of data. In between there might be methodology shifts and re-evaluations etc., which might deteriorate the effects of real trend changes. A rolling 10 year trend might well be a better solution from a methodological point of view? There would be the risk of missing the actions taken by early movers but on the other hand, it is not perhaps desirable to have a high trend position based solely on ancient history.

5.1.4 Level and trend combination

Level and trend are combined into a single score with equal weights. This raises some thoughts. Can we say that this country is overall better than that country, even though it has a much worse energy efficiency level? That is what combining the two scores is doing, at least in the mind of the viewer. But are equal weights the right way to go, or should the trend for example be weighted by the level score as already suggested for trend itself? The higher the level of the efficiency, the more valuable is a relative improvement.

5.2 Transport sector

The transport sector scoreboard comprises indicators as presented in Table 15.

Table 15. Scoreboard indicators for transport sector (ODYSSEE 2018e)

Modes	Indicator	**Weighting factor**
Cars	Specific consumption (l/100km)	Share of cars in total transport consumption
Trucks and light vehicles	Specific consumption (goe/tkm)	Share of trucks and light vehicles in total transport consumption
Air	Specific consumption (koe/pass)	Share of air in total transport consumption
Modal split: -Passengers -Goods	% of traffic by public mode % of traffic by rail and water	Share of buses and rail passengers in total transport consumption Share of water and rail freight consumption in total transport

In the level scoreboard for the transport sector, Italy is the best country, Slovakia second, UK third and Finland is 7th and Sweden 9th. If trend is added, where Finland is second worst, Finland tumbles to 17th and the UK and Sweden form the top. Going into individual indicators, see Table A1 in Appendix 1, car efficiency is the most important as it carries the by far largest weight.

5.2.1 Car efficiency

UK has the best car efficiency level and trend. However, according to the database, UK´s efficiency 2015 is 7.6 l/100 km, one of the worst values. In the scoreboard indicator numbers, UK has the best value, 5.9 l/100 km. Very bewildering. Slovakia's database entry is N.A. for the whole time period, but the scoreboard value is 7.4 l/100 km and a second place is scored in the level category. Finland has a value only for year 2000, although it in itself is very competitive to other's values of 2015.

Bulgaria, Czech Republic, Lithuania and Romania have no "Average specific consumption (l/100 km) of cars" data available in the ODYSSEE (2018d) database, but they still outperform Finland in the car efficiency trend. Malta has no data, and Malta receives 0 on level and 0 on trend.

The question arises, why use litre/100 km as car efficiency indicator? Litre is a non-energy unit, and especially for increasing electric vehicles, will have no relevance what so ever. A diesel litre's energy content is different from a gasoline litre, which in turn is different from a hydrogen or LNG or whatever litre. In addition, the database in ODYSSEE is lacking, which quite a lot of missing data. Wouldn't it be better to use an indicator where there is more data coverage, e.g. kWh/km? Interestingly, using ODYSSE (2018d) data and taking the average of 2013 to 2015, the level results would look a bit different, see Figure 12.

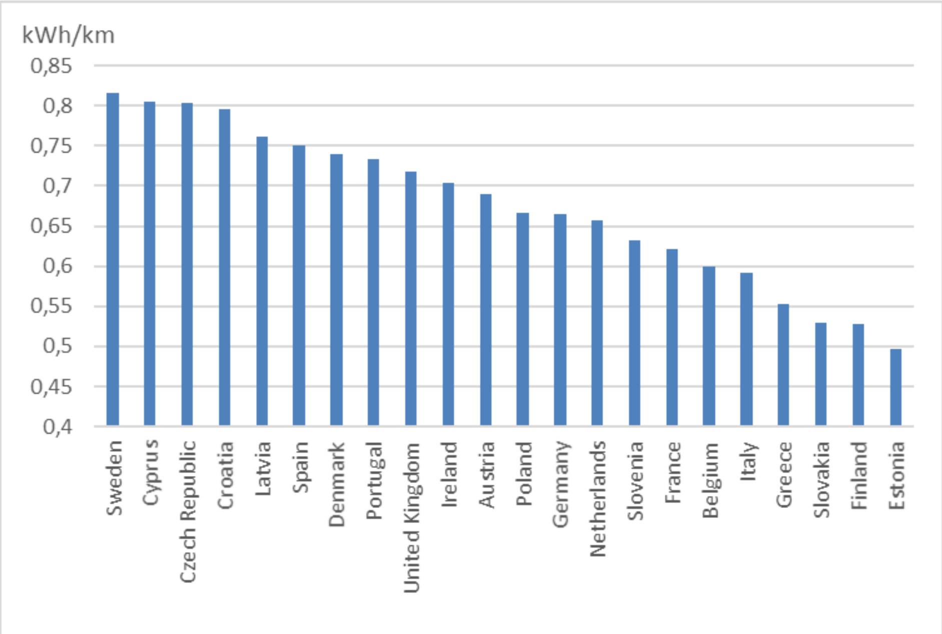


Figure 12. Car efficiency expressed as kWh per km (data: ODYSSEE 2018d).

Here, Finland has the second best score next to extremely good Estonia. Slovakia and Italy would also be in the top, UK in the middle and Sweden at the bottom.

The trend indicator in the scoreboard indicates that Finland is only better than Malta and Cyprus. NB! The path is totally different, as Finland's original position was very good in year 2000, but Malta's and Cyprus' original positions not so. However, Finland loses in the trend scoreboard to countries that do not have any data at all, for example to Romania.

If we look at the trend as measured by kWh/km, the result is quite different again, see Figure 13. Finland would present a 10% overall reduction and would be in the middle of the gang, achieving 0.55 score points. Here, Romania has data and gets a score, 0 points. The question arises, how can one present the scoreboard, as it is, as an objective ranking of countries? Well, one cannot and should not.

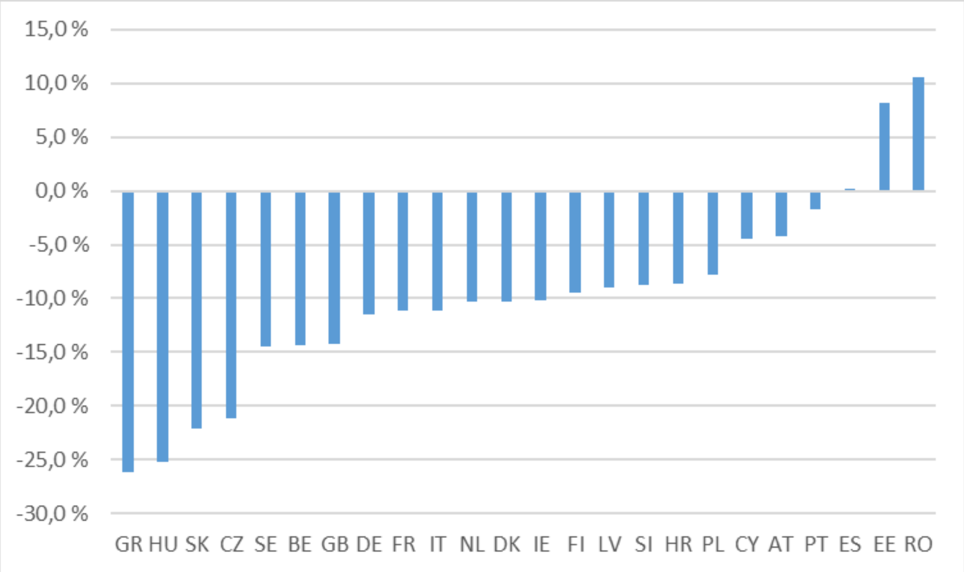


Figure 13. Change in car efficiency from 2000 to 2015.

5.2.2 Road freight

The indicator selected, road freight per tkm, is suitable for this purpose.For lack of knowledge, we won't here go deeper into how the statistics are formed and what is included in a national statistic and what not, e.g. transit traffic or untaxed fuels. Italy was 5th, Slovakia 11th, UK 25th, Sweden 18th and Finland 23rd in the freight level score. As for trend, Finland is third worst, beating only Italy and Luxembourg.

The best unit consumptions are shown by Eastern European countries and the smaller island states, Malta and Cyprus, have over ten times larger unit consumptions than that. Finland shows unit consumptions that are around 40% larger than Sweden and three times as large as Denmark. Denmark has also a small but negative trend, while Sweden shows a 1% increase for each year and Finland a 3% increase. The Finnish negative development stems mainly from 2011 to 2013, when activity level decreased with 15% while the fuel consumption only decreased with 3%. The activity level in 2016 is already back at the level of 2011, but there is no consumption data available yet.

5.2.3 Air travel

Air transport is evaluated in energy per passenger. What more, data gives up that this includes both domestic and international flights. **Is this really a fair method, as some are situated in the periphery, a long way from Brussels, while others are in the middle of Europe?** Some countries have also large amounts of intercontinental flights, for example from London to North America and from Finland to Far East, which need considerable more energy than short flights inside Europe. Since many countries do not have domestic flights (9 didn't have statistics on kWh/pkm for domestic flights[12]), and ODYSSEE statistics does not

[12] 9 countries didn't have any data. Three had sporadic data, which is still OK. But the range of the values, from 0.02 kWh/pkm in Latvia and 0.03 kWh/pkm in Slovakia (even electric cars with 4 persons

have pkm data for domestic and international flights (would it be available?), a rather unfair meter is in fact then used. As Luxembourg has a value of roughly double the second worst, this affects the score point calculations, as all other gets points between 0.5 and 1. This benefits those who would otherwise have low values, e.g. UK as the second worst gets 0.5 instead of 0 point, and it squeezes the realised point variation.

5.2.4 Public transport and rail and water freight

This indicator is meaningful and gives a broad but fair picture. Public transport and rail and water freight are desirable targets in themselves, and a modal change hereto is to be applauded. The indicator describes just that, without going into unnecessary petite details of unit consumption etc., where statistics themselves might produce extra pains. The scoreboard avoids, for example, these unnecessary detail pitfalls:

- Spain's train transports use roughly 1/3 of the energy beginning 2013, with unchanged activity levels. Electrification does not seem to be the answer to this mystery, perhaps privatisation and statistics gathering changed? This will result in the weight factor for public transport and rail freight to be reduced, but the change is very small.
- Portugal has a statistics breakpoint 2011/2012: consumption of cars drop by 24% while passenger-km drop by only 1%; motorcycles consumption has a drop of 68%. This will increase the weight of public passenger transport, but as the points are low, the impact will not be that large.
- Finland has a relatively high water freight unit consumption, seven times higher than Sweden and a decade higher than Germany and almost as high as for road transport of goods. The reason behind that will not be further investigated here, it might have to do with coastal and sea transport versus river transport or in how passenger use is calculated/separated. As Finland has a high share of rail&water freight, the "heavy" consumption increases the weight and improves the Finnish scores.

5.3 Households

The household scoreboard comprises indicators as presented in Table 16.

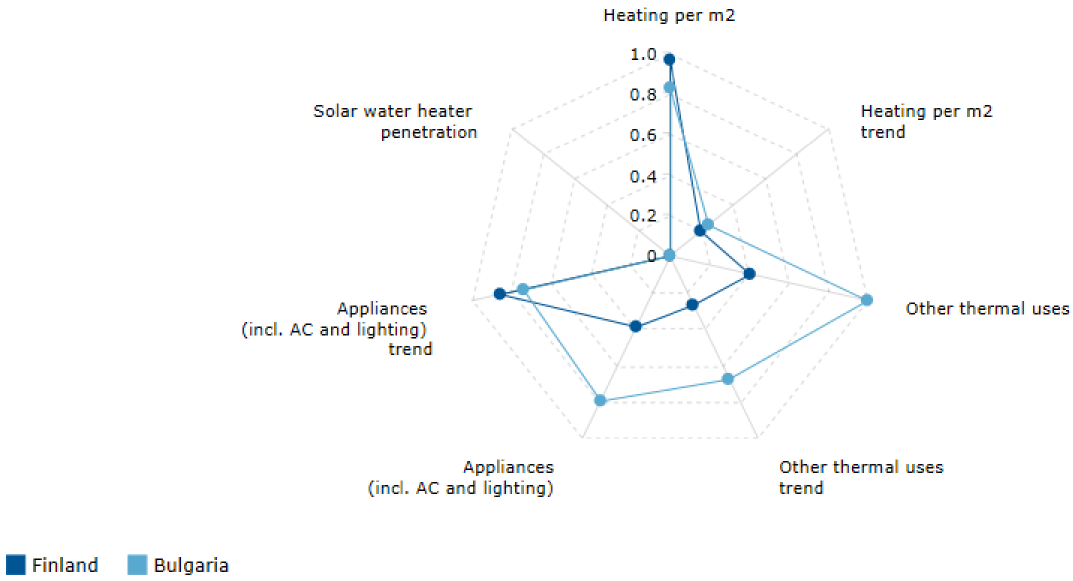
jammed into them wouldn't reach this excellence!) to normal range 0.5…2.5 kWh/pkm and then some countries with clearly higher values, with Czech Republic at 33.6 kWh/pkm.

Table 16. Scoreboard indicators for households (ODYSSEE 2018e)

End-use	**Indicator**	**Weighting** factor
Heating	Consumption for heating per m2 scaled to EU climate and equivalent to central heating	Share of heating in total households consumption
Other thermal uses	Consumption per dwelling for cooking and water heating	Share of cooking + ½ of water heating in total households consumption[13]
Appliances	Specific consumption of electricity per dwelling for appliances (including AC) and lighting	Share of appliances (incl. AC) & lighting in households consumption
Solar penetration	% of dwellings with solar water heater	½ share of water heating in households consumption

If we look at the level indicator, Bulgaria is the best performing country, followed by Lithuania and the Netherlands. Finland is sixth and Sweden 16th. The trend scoreboard evaluates Ireland highest, Portugal second and Romania third, with Sweden #18 and Finland almost last of the litter, at #28. The scoreboard comparisons between of both Bulgaria and Ireland to Finland is presented in Figure 14. The combined score gives the order Ireland, Netherlands and Slovakia, with Sweden #16 and Finland #20.

[13] Two indicators are related to water heating: the other thermal end-uses and the solar penetration. In order to have consistent weights (totalising 100%), we apply an equal weight between the two indicators equal to half of the share of water heating in total households consumption.



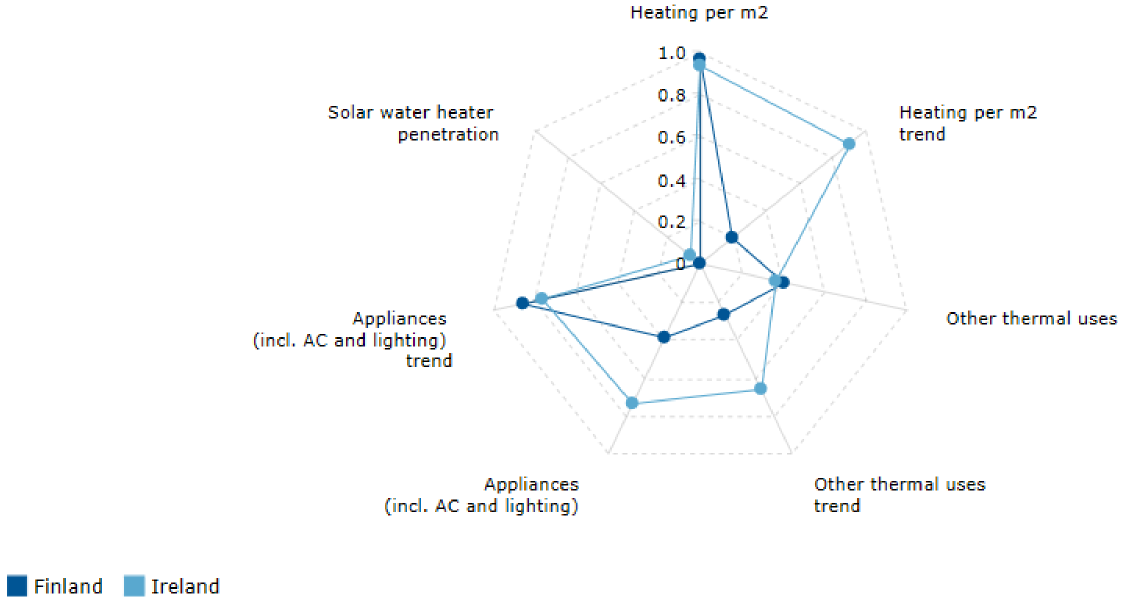


Figure 14. Scoreboard comparison of household energy efficiency level between Bulgaria and Finland, top, and Finland and Ireland, bottom. (ODYSSEE 2018f)

Although Bulgaria and Lithuania are the overall leaders in the household level scoreboard, could there be other reasons than energy efficiency excellence? To be honest, Bulgaria and Lithuania are also the European leaders in the share of dwellings experiencing inability to keep homes adequately warm, with 39% and 31% respectively (Eurostat 2018b).

5.3.1 Heating

Heating is evaluated as per square metre and scaled to EU climate and equivalent to central heating, which is a fair approach.

1. Heating per m2 is fair as heating per dwelling would not capture the fact that larger dwellings need more heating energy.
2. Scaled to EU climate is also fair, as the same house and heating system providing the same comfort would need a lot more heating in a cold climate than in a warm climate, and energy efficiency is all about the goodness of the house and the heating

system. The used heating degree days (HDD) of average EU climate is not to be found in (ODYSSEE 2018a-g). Is the EU reference climate calculated from the reference HDD of the individual countries, and if so, how: average or weighted average? Or is the EU climate as presented by Eurostat used as reference? If the former, the problem lies in that national HDD's are not calculated in the same way. If the latter, there is also a problem. The national reference HDD's in ODYSSEE are initially for national use, for normalization of heating demand, and differ from the definition that Eurostat (2018a) uses. For instance, the HDD_{ref} for Finland is in ODYSSEE (2018d) 4517 but 5646 with Eurostat (2018a) data and reference years 1990-2015 (same time period as JRC (Economidou 2017)). ODYSSEE also uses an elasticity of 0.9 for adjusting heating requirements, while for example IEA (2017b) and JRC (Economidou 2017) use an elasticity of 1.

The correct methodology would be to have normalization done using ODYSSEE HDD and HDD_{ref} and the scaling to EU average climate using Eurostat/JRC HDD and HDD_{re}f for both national reference and EU climate references. The Eurostat HDD's are formed using the same definition for all countries although a small snag is found in that, according to ODYSSEE (2017), only the arithmetic national average, not the population weighted national average, is published and available on the web site.

3. The penetration of central heating is mainly significant in the southern European countries and in Ireland. Central heating (around 85% of EU dwellings in 2009) , which includes district heating, block heating, individual boiler heating and electric heating, implies that all the rooms are well heated, as opposed to room heating, where generally a stove provides heat to the main room only. A dwelling with room heating consumes 25% less than a dwelling with central heating. (ODYSSEE 2017)

   ODYSSEE has chosen centrally heated houses as the target service level. Equivalency to central heating corrects low energy consumption for non-efficiency reasons, for example, that not all rooms are necessarily heated in the winter. Is it fair or not, that is debatable, just as is energy conservation energy efficiency or not, but if we are comparing countries, we do like to use a level service level in the comparison. For room heating to achieve equivalency to central heating the consumption is multiplied with 1.33. A reduction in the number of room heated houses will thus have a positive effect on energy efficiency to compensate for the increased energy consumption. On the other hand, increasing central heating might not have that a large effect on the consumption for energy poors.The penetration data of central heating in each country is not to be found in ODYSSEE (2018a-g).

The highest level scores go to Sweden, Norway and Finland, with Ireland fourth. The Netherlands is #6, Lithuania #11 and Bulgaria #12.

The high scores for Ireland are related not so much to energy efficiency but to energy conservation, which is interesting especially in view of ODYSSEE's viewpoint of emphasising technical savings over behavioural savings. The insulation can be so flimsy in many houses that all the heat just vanishes, so it makes sense not to heat for the crows when absent. Heating is commonly turned off when leaving the house and turned on when returning. However, the approach is good and with a smart home energy management system, this energy saving approach can be taken without loss to service level.

Trend

As for the trend, Romania, Ireland and Latvia are high, with Sweden at #18 and Finland, if it were not for Malta, last. Without data, it is hard to assess how much a change in the share of central heating is behind these results. A high impact would not be desirable taking into account the uncertainties associated hereto. How big is the difference in energy use between centrally heated and room heated houses in the different countries? For Ireland, the difference might be smaller than 25% as Irish heating habits are different and the habits would stay as they are even when switching to electric heating[14]. The change in share of central heating, and change in overall heating consumption for that matter, could perhaps be set in relation to energy poverty. In Ireland, for example, the share of houses not being able to keep them warm has increased from 3.2% in 2003 to 9.0% in 2015 (Eurostat 2018b). This might be one explanation adding to the trend statistics.

The Finnish trend is seriously affected by the correction to normal climate. Year 2000 was warm but 2015 even much warmer, and as the HDD-calculations overcompensate, lifting the normal year consumption too high, it appears that the trend has been much smaller than it in fact has been, see Figure 15. If we look at Swedish data, see Figure 16, we see they are more lucky regarding overcompensation as year 2015 is much colder than year 2000. We can also note, that although year 2000 is much warmer than year 2001, the actual heat demand does not budge. Similarly, from 2014 to 2015 it gets colder and actual heat demand is despite that clearly reduced. **Can it be that Swedish space heat demand in ODYSSEE is already normalised, so now it gets normalised twice? Something fishy is going on.**

Depending on what HDD’s are used, the trend might look different, as some countries are using a sliding reference value for HDD. The use of an elasticity of 0.9 might be optimal for normalisation, but is it for comparing to EU climate? As seen in the decomposition analyses by IEA and JRC, they use an elasticity of 1.

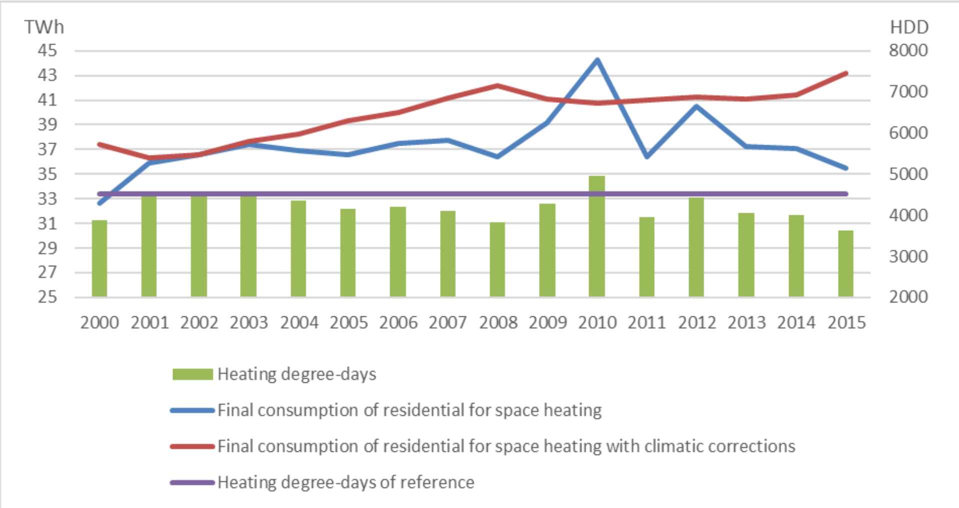


Figure 15. Overcompensating Finnish heating demand from extreme years to normal years. (Data source: ODYSSEE 2018d)

[14] See for example H2020 project RealValue at www.realvalueproject.com.

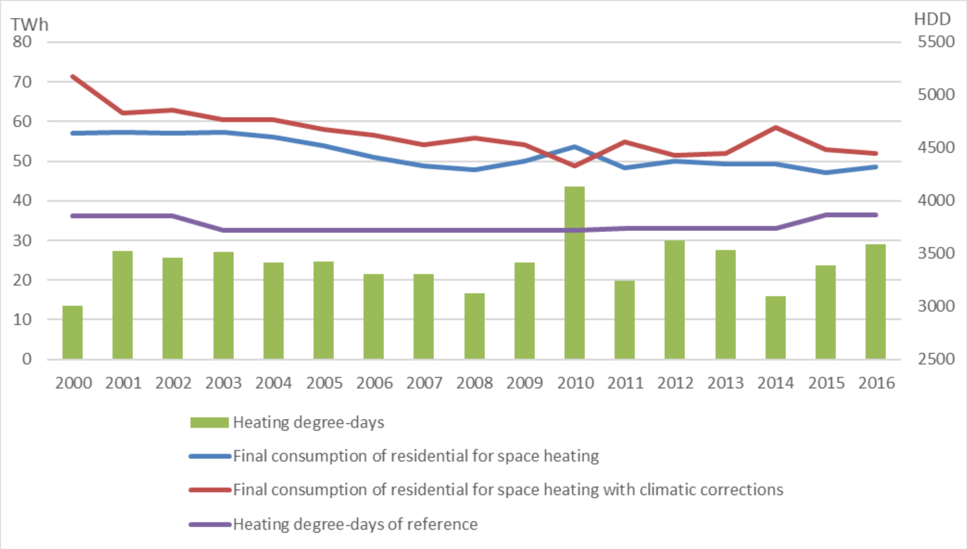


Figure 16. Swedish space heating demand, overcompensation and strange behaviour. (Data source: ODYSSEE 2018d)

Scores

If we look at the scoring, we can calculate that Romania scores better overall points than Finland or Sweden, although the unit consumption is three (3) times as high. An energy efficiency ranking system like this seems a bit preposterous. So, as already mentioned earlier in this Chapter, trend scoring should also be related to the level.

If we look at heating values, koe/m2, Croatia has the highest value, 29.46, the difference to the next highest, Belgium at 22.05, being more than the lowest value itself, Sweden with 6.56. This results in a very tight evaluation for most countries.

5.3.2 Other thermal uses

This is measured as consumption per dwelling for cooking and water heating. Bulgaria, Lithuania and Greece top the level scores. Sweden is #7 and Finland #21. For trend, UK, Hungary and Portugal are the leaders of the pack, with Sweden at #22 and Finland at #27.

To look at water heating as per dwelling seems a bit inappropriate, as most energy use is related number of persons and mainly showering/bathing and hand washing. Of course, households without washing machines need warm water for washing of dishes and clothes. Anyway, Germany and Finland are the beneficiaries of this, while states with large households, like Slovakia and Poland, are the payers. Cooking is mostly not a question of energy but of behaviour. Differences might be due to income, but also to skill sets and overall behaviour changes. For example the use of microwave ovens has presumably been increasing, but it is part of captive electricity use, not cooking.

Water heating energy use is, for example, a decade larger than for cooking in Finland and Sweden, but only approximately four to five times larger in the UK and German and on the other extreme, half or less in Romania and Portugal. Romania and Portugal exhibit 4 to 5 times larger cooking energy per dwelling than Germany that in turn exhibits 2 to 3 times larger unit consumptions compared to UK, Sweden and Finland, so there is quite a variety. Are Romania and Portugal, who both have low unit consumptions for water heating, perhaps warming domestic hot water on cooking stoves? Solar heat seems not to be part of database input for energy used for water heating, or if, only in some countries but not in others. This might explain some differences and the low unit consumptions per person in most Southern European countries.

Cooking data for Finland is available from year 2007 onwards. It is hard to say how this affects the trend as the rules for missing data are not stated.

Water heating

The difficulty is that most systems usually measure just the heat use in dwellings. The division of the energy consumed between space heating and domestic hot water is probably done using models or assumptions.

Looking at ODYSSEE (2018d) data for Finland, a share of 81.5% of heating was allocated to space heating and a share of 18.5% to water heating 2000-2007 and after that, the fluctuations in the heating demand due to weather were taken into consideration. This has an impact on the trend, as 2000 was a very warm year, resulting in a very low water heating estimate. Comparing the trend to this low value will not give a positive picture. In absolute consumption values, hot water heating has increased 23% from 2000 to 2015, but only 12% from 2001 to 2015.

Germany has a change around 2007and 2008, perhaps even a break point in the time series, with water heating consumption increasing. It is a reason Germany fares so badly in the trend. The reason behind the increase is an overwhelming growth of the use of wood, with an accompanying share increase from 3% in 2005 to 22% in 2008. The share of oil use decreases for this period from 22% to 17%. This is the main reason Germany is second worst in the trend scorecard of Other thermal use. Quite a dramatic change, but perhaps more the result of new statistical research than of a real change.

The UK, on the other hand, has a 24% improvement of water heating absolute consumption 2011/2012, and again 16% in 2013/2014, which to a degree explains UK's leading trend position. Stepwise improvements take place as studies are not done every year, so the changes can represent compound effects, or be results of energy saving campaigns, but also origin from a change in methodology. The large improvement in UK does lead one to think that this is not an energy efficiency improvement but a methodology improvement.

Sweden has a time series break in 2015. Energy use for water heating increases, though for cooking decreases.

5.3.3 Electrical appliances and lighting

Electricity used for other purposes than heating or cooking is estimated per dwelling. Some of the uses are perhaps more in relation to square metres, some to number of inhabitants, but dwellings is an acceptable solution.

In this category, the winners are Estonia, Czech Republic and Portugal, with Finland as #28 and Sweden as #30. Eastern European states, together with Germany (#10) and already mentioned Portugal, fill the top 11 placements. Finland's unit consumption per dwelling is 80% larger than in Germany, although large application penetration is 10% to 30% larger in Germany. Finnish placement can be explained, at least partly, by electrical saunas. The use of heat pumps in the summer for cooling, with 2.8 million dwellings and 0.7 million heat pumps, might not be such a minor issue in “cold” Finland, as summers can be hot. Another factor is the use of electric car preheaters (common also in apartment building parking areas) in the winter. The need for more lighting during the winter, with extremely short days, might be another explanation; light summer nights do not counterbalance this as people are asleep at nights. It helps Finnish scores that Sweden has such a high unit consumption per dwelling. If Finland were the worst, Finland would get 0 points instead of now 0.39 points and, for example, Germany would get 0.61 instead of 0.76. The difference between Finland and Germany would increase to 0.61 points from 0.37 points now.

Looking at the trend scoreboard, we have Malta, Finland and Slovenia in the top. One explanation might be Finnish use of electricity for heating through auxiliary air-air heat pumps, bathroom floor heating etc., which due to a statistical methodological change 2007/2008 was moved from electrical appliances to electrical heating. This has presumable not been done in Swedish statistics, which might be the reason Sweden shows decidedly higher unit consumptions.

5.3.4 Penetration of solar water heaters

There is only the level score in play for this indicator: Bulgaria is 26th, Lithuania 29th, Netherlands 12th, Sweden 19th and Finland 25th. Cyprus is the leader with a penetration of 73.2%, Greece has 30.2%, Austria 19.4% and Switzerland 10%. (ODYSSEE 2018f)

The large spread gives good points to Cyprus, Greece and Austria, but for the rest it is no big deal if the penetration is 5% or nil. Switzerland's 10% is a bit big, as there is no data behind it ODYSSEE 2018g). One of the reasons for not having a trend might be explained by the data found in EU buildings database (2018) of the share of dwellings with solar heating system. Bulgaria had exactly the same penetration as Cyprus between 2000 and 2005, where after it dropped with over 70 percent units. A sign of the quality of statistics at the turn of the century? Although there is data from 2015 in ODYSSEE (2018g), the scoreboard (ODYSSEE 2018f) uses data from 2013.

Solar heat is not part of database input for energy used for water heating, or if, only in some countries but not in others. For example, in both Ireland and the Netherlands over 4% of dwellings have solar water heaters, but looking at energy input to water heating, only fossil fuels and electricity is used. In addition, if we analyse water heating consumption per person, Spain, Malta, Greece and Portugal have among the lowest unit consumptions, less than 0.6 MWh per person. Cyprus has a more normal unit consumption, although solar water heater penetration is above 70%. (ODYSSEE 2018d, g).

Is the use of share of dwellings with solar water heaters as an indicator a double whammy (as heat professionals like to say) for solar heating? It first of all reduces the amount of energy that is in the statistics for water heating, improving the indicator result for other thermal uses, and then again gets points here?

Use of solar water heaters feels also a bit lopsided. They are more economical in the Mediterranean area where production can be up to three times as large (NB: this for PV, solar heaters might be a bit different) with the same panel than in Northern Europe. On the other hand, heat pumps are also used to generate gratis, renewable heat for water heating. Why is not their penetration included?

In conclusion, this indicator is a bit lopsided and under suspicion of providing redundant information.

5.4 Industry

The industry level scoreboard focuses on the indicator Adjusted energy intensity at EU industry structure. According to ODYSSEE (2018e), the energy intensity of industry at EU structure represents a fictitious value of the industrial intensity calculated by taking for each industrial branch the actual sectoral intensity of the country and the EU industrial structure (i.e. the share of each branch in the value added of industry). For Finland and Sweden, as pulp & paper represents around half of the total industrial consumption, the adjusted indicator is based on physical quantities instead of value added for pulp & paper (production of paper and pulp) and on VA for the other branches.

As noted several times before, energy intensity per value added is a poor indicator of energy efficiency.

For level scorecard, Switzerland, Italy and Lithuania are in the top, followed by the UK, with Sweden as #19 and Finland as #24. Looking at the trend, Lithuania, Bulgaria and Poland are in the top, with Sweden as #25 and Finland last, as #29. Eastern European countries dominate the 10-top of the trend indicator, with only Cyprus (#8) and Ireland (#10) elbowing their way in.

According to ODYSSEE (2017), only the physical production of paper, not pulp, is under scrutiny. Unit consumption of paper is thus “Final consumption of paper, pulp and printing industry” divided by “Production of paper”[15]. This results in a competitive disadvantage for all countries producing also pulp, as the energy is counted but not the physical production. As already mentioned in Chapter 0, pulp and paper production is very energy intensive and the energy intensity varies depending on the end product, raw material (recycled paper or raw wood etc.) and production process (e.g. mechanical or chemical pulp), which are not energy efficiency questions. As pulp and paper has such a tremendous importance for Finnish industrial energy use, any methodological shortcoming such as this will seriously affect the comparability and usability of the results.

ODYSSEE uses production tons and unit consumptions per production as a measure, which is a good thing. To use energy intensity would have been worse. However, instead of only having the production of paper as denominator, how hard would it be to have unit consumption of pulp and paper, with the same energy amount but adding the production tons of pulp? The results would have been better comparable, see Table 17. Finland and Sweden would be much better situated. If the share of virgin pulp were taken into account correctly, their placement would surely be even better.

Table 17. Unit consumptions and energy intensity of the pulp and paper sector and the change from 2000 to 2015 (Data source: ODYSSEE 2018d)

	Unit consumption of paper, MWh/t	Unit consumption of pulp and paper, MWh/t	Energy intensity of pulp, paper and printing[16], MWh/1000€
Finland	6.61 (0.9%)	3.41 (- 1.8%)	20.66 (- 8.7%)
Sweden	7.47 (4.3%)	3.61 (4.3%)	17.80 (62.9%)
Italy	3.08 (- 9.4%)	3.08 (- 3.4%)	2.87 (- 3.7%)
Lithuania	2.48 (-73.2%)	2.48 (-73.2%)	1.00 (-80.8%)
UK	6.18 (43.5%)	6.18 (43.5%)	2.10 (7.7%)

Steel consumption is evaluated per produced ton, but the two main processes, oxygen blown converters and electric furnaces, are not separated. This will seriously affect the results, as

[15] For example, Cyprus, Estonia, Ireland, Latvia, Luxembourg, Malta and Slovenia have no paper production at all. How is that taken into account in the adjusted energy intensity indicator at EU industry structure?
[16] Value added of paper and printing / Final consumption of paper, pulp and printing industry.

electric furnaces use less energy, but the use depends on, among others, available raw material, so process selection is not directly an energy efficiency question.

Cement manufacturing is also an energy intensive industry branch, with some parts needing more energy, like making of clinker, and some less. As Finland has so few manufacturers, this branch cannot be analysed separately but added to other industries, affecting the scoreboard results. As this is an energy intensive industry, adding it to Other industry will make Other industry fare worse. Depending on how missing time series is handled, Finland might additionally get low points from Cement production.

As already noted earlier, value added is not a good indicator of energy efficiency. Especially not for energy intensive bulk products, but neither for other industry production. For example, Finnish energy intensity development has been heavily influenced by the rise and fall of Nokia mobiles. Nokia mobiles was a high value added end-user product which required relatively little energy to manufacture. Communication equipment (Nace 3 Branch 263) turnover has been decreasing since 2007, to just one third in 2016. Value added decreased also and even presented a negative value in 2012 (StatFin 2018). The ODYSSEE Machinery branch (NACE rev 2 Divisions 25-28 and 33) development in Finland is shown in Figure 17. The financial crisis really affected the value added of this branch in all aspects, not only Communication equipment, but most other branches have partially recovered.

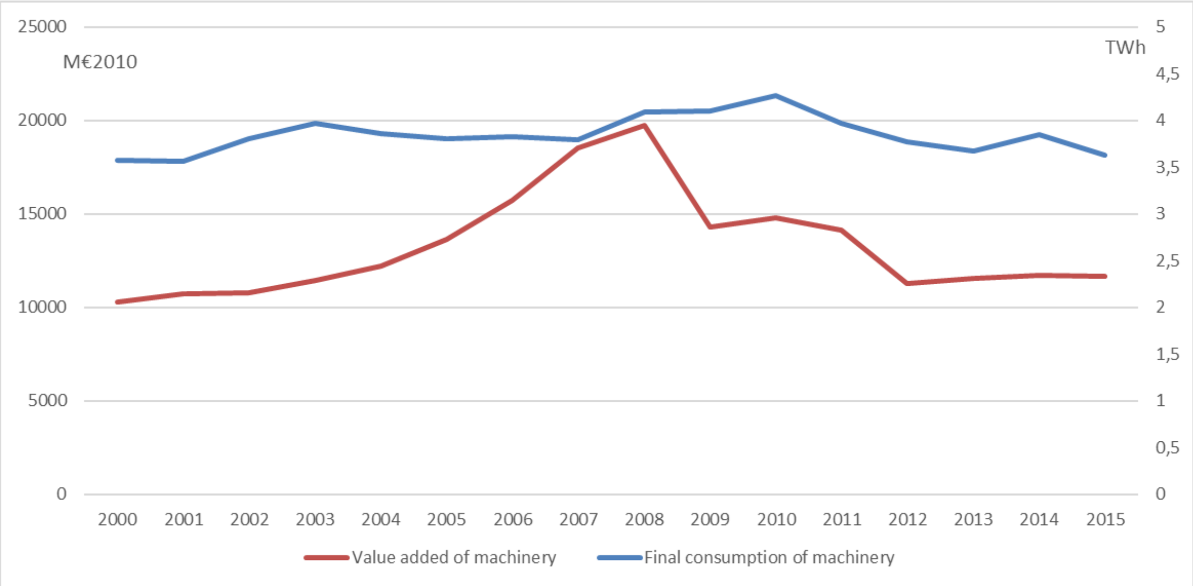


Figure 17. Development of ODYSSEE/Machinery branch 2000-2015 in Finland. (Data source: ODYSSEE 2018d)

The industry scoreboard uses as indicator of trend the energy efficiency index of industry, ODEX. ODEX is designed in such a way that it only approves improvements and is calculated on a year-to-year basis, which might severely hampers its usability here. In addition, the criticism presented for the level indicator is valid also for ODEX. ODEX relies on the same principles. If we look at the Gross ODEX (unadjusted) and Technical ODEX for selected countries (Figure 18), we see interesting features.

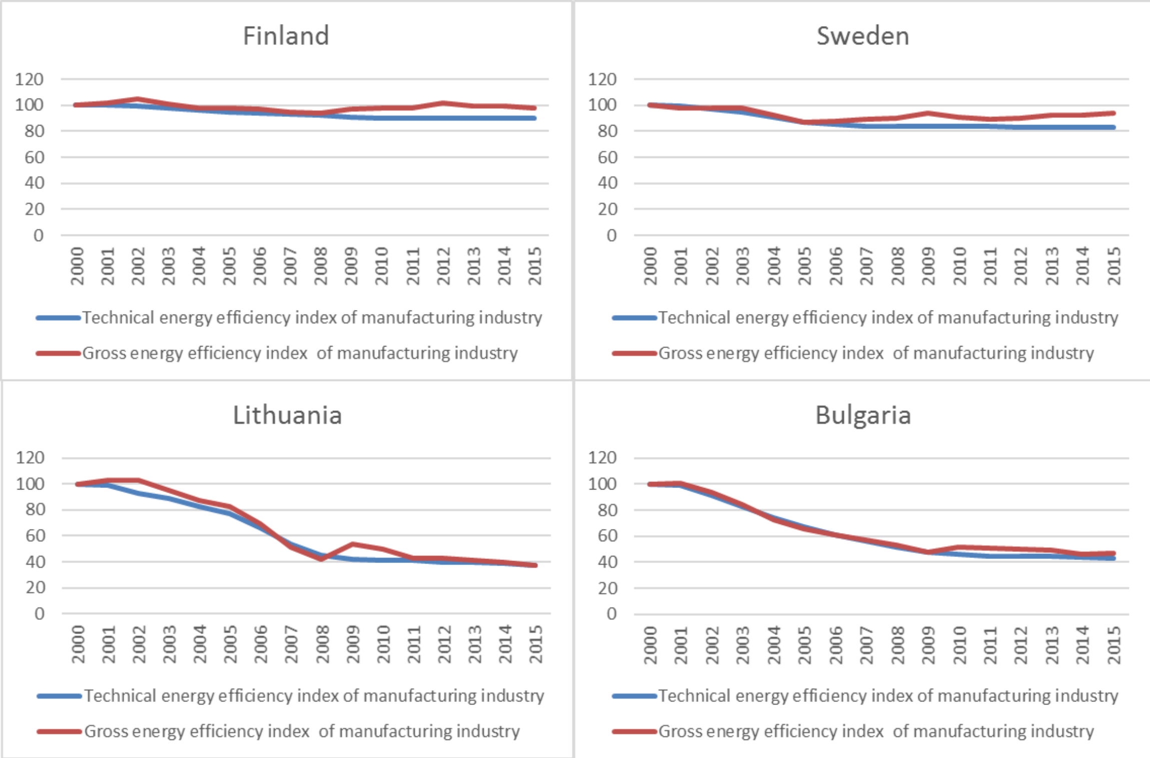


Figure 18. Gross and Technical ODEX of Manufacturing 2000 to 2015. (Data source: ODYSSEE 2018d)

The Gross index can be lower than the technical index, which is interesting, but has to do with using three year's average in Technical index. For Finland and for Sweden, there is a big gap between the two types of indices. Both Bulgaria and Lithuania present astonishing energy efficiency improvements. According to technical ODEX, energy efficiency in Lithuania improves by 49% from 2003 to 2008 and in Bulgaria 37%. The index for Industry is very similar to that of Manufacturing industry for the four countries. To be able to better assess this process, a deeper analysis of individual factories should be performed than what is done here. For the period 2000 to 2015, using ODYSSEE (2018d) data:

- Bulgaria almost doubles the production of paper (pulp statistics is not available), but energy use rises with 157%, resulting in Bulgarian unit consumption for paper to increase by 30%.
- Bulgarian steel production decreases 62% and hereto related energy use 84%, bringing an improvement of 58% to unit consumption of steel. The share of electricity use increases from 21% to 55%.
- Paper forms 9.0% and steel 4.1% of total use of energy in industry in Bulgaria in 2015.
- Lithuania produces almost two and a half as much paper, but the energy consumption decreases nevertheless with 35%. Unit consumption of paper improves by 73% to 2.5 MWh/t.
- Lithuanian steel production is negligible.
- Paper forms 2.8% and steel 0.2% of total use of energy in industry in Lithuania in 2015.
- As comparison, paper forms 55.1% and steel 11.3% of total use of energy in industry in Finland in 2015.

As steel and paper production forms such as small share in Bulgaria and Lithuania, all other sub-sectors must also have really good efficiency improvements, due to energy efficiency actions, product changes, closing of factories, statistical time series break points etc. On the other hand, energy efficiency levels have be terrible to begin with to be able to perform over 50% improvements in a decade.

In conclusion, ODYSSEE Industry scoreboard does not picture the energy efficiency development correctly, as the indicators behind it are skewed, one sided or biased or just measure other phenomena. To compare countries with each other is something that should not be made without excellent and detailed tools. The ODYSSEE Scoreboard is too simplified to present a trustworthy result.

5.5 Service sector

The service sector scoreboard comprises indicators as presented in Table 18.

Table 18. Scoreboard indicators for service sector (ODYSSEE 2018e)

End-use	**Indicator**	**Weighting factor**
Thermal end-uses	Thermal end-uses consumption[17] per employee scaled to EU climate	Share of thermal end-uses in total services
Electricity	Specific consumption of electricity per employee (including AC and excluding thermal uses[18])	Share of specific electricity consumption in total services

Looking at the energy efficiency level, Lithuania, Portugal and Spain are in the lead, with Sweden (#21) and Finland (#29). As for trend, Hungary, Sweden and Luxembourg form the top and Finland is 12th. In the combined scores we have Portugal, UK and Ireland in the top, with Sweden as #6 and Finland in the bottom.

To use employee as denominator for thermal end-use is questionable, as space heating is so focused on the building. For example, building cubic metres would be better. Building floor area can be used instead of cubic metres, if availability of the statistics is found to be an issue. Availability is an issue, and even data on floor areas is lacking in the ODYSSEE (2018d) database for many countries, which is the probable reason that the wrong denominator (employees) is used.

A deeper analysis of how personnel numbers relate to tasks performed in different countries (pupils, patients, hotel rooms, secretaries per other staff etc.), how the number of employees are gathered and can outsourcing to one person companies, with only self-employed entrepreneurs etc. have an impact etc. has not been done in this study.

Even use of electricity can in many sub-sectors be better related to floor area than personnel, as the number of employees per service done is perhaps more an indicator of the wage level, service level and personnel intensity than energy efficiency. For example:

- Schools: teachers and staff do not directly use electricity that much but the building does (AC and lighting).
- Food market: employee direct use of electricity is probably small compared to AC, lighting, freezers and fridges, which should correlate with size of the store.

[17] For countries for which the data by end-use are not available, the total fuel consumption is taken.
[18] For countries for which data by end-use are not available, the total electricity consumption is taken.

- Hotels: employees do not directly use electricity that much but the building and the clients do, so the number of rooms and the size of the building (AC and lighting) is determinant. Modern economy hotels might not even have receptions.

- Hospitals: electricity use is determined by patient needs and by the size of the building (AC and lighting, freezers and fridges). Nursing staff per patient is more of a service level indicator.

- Restaurants: personnel direct use of electricity is probably small size of the building (AC and lighting) and other uses (freezes, fridges, cooking apparatus).

- Offices: personnel direct use of electricity, mainly computers, is a main factor along floor area based AC and lighting. As employees are physically quite concentrated normally, this will affect the need for AC (and, in all fairness, reduce heating demand). Referring to decomposition methods, employee could be the activity, floor area per employee the structure and energy consumption per floor area the energy intensity.

As the branches differ so much, a useful analysis would need branch wise information, and the decomposition analyses should be done similarly as to the industry. In ranking, the branches should also be weighted to an average EU structure to be to at least some degree comparable. As it is, the service sector scoreboard is far from this desired state.

5.5.1 Thermal end-use per employee

Thermal end-use level is best in Greece, Cyprus and Portugal, with Sweden as #20 and Finland as #29. Southern European countries are generally in the top and Northern European countries in the bottom, although Norway is in fifth place.

Actually, only 10 countries of EU-28 have thermal use data in the ODYSSEE (2018d) database. There is no data for Norway, so fuel consumption data is used. However, Norway uses electric heating as much as they ski, so this is clearly a misjudged position. Among other countries that do not have heating data available, but use electricity over 5%, we find Bulgaria, Greece and Ireland, see Figure 19.

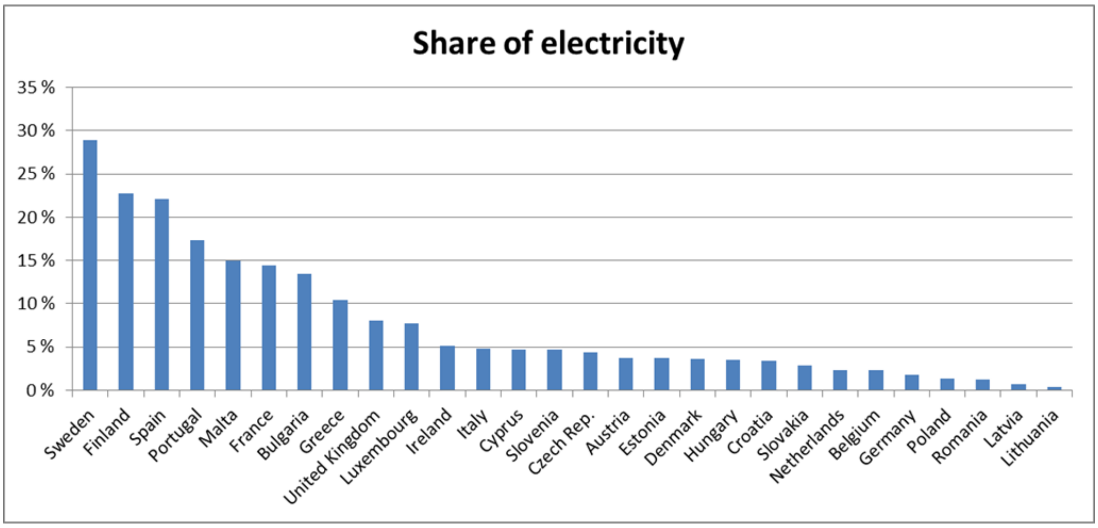


Figure 19. Share of electricity in space heating in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011, and UK 2012). (Source: Grandell et al. 2016, which used data source: Enerdata 2015)

If we use ODYSSEE (2018d) data, we find that Finland has a better space heating unit consumption than, e.g. Portugal, Spain or Sweden. However, the indicator is about thermal use, so we must add cooking and water heating. Finland has a very high share of water heating of total heating. Of all heating, it is 40% in Finland (a constant!), 25% in Portugal, 18% in France, 12% in UK, 9% in Germany, 7% in Sweden, 6% in Spain and 2% in the Netherlands. The share of water heating is very large in Finland, as for example absolute heating demand in Portugal, the owner of the next largest share, is very low. If we assume that part of the 40% share of heating is actually heating and not water heating, this would improve Finnish statistics as heating is corrected to EU climate.

If we look at thermal use per floor area, Finland is clearly better than those tested that had data; Spain has a 96% larger use, Sweden 16% and UK 66%. Finland had also the best trend, clearly beating for example Sweden, the #8 on the trend scoreboard, and the UK, #9.

For the scoreboard trend, as 2015 was warmer than 2000 in Finland, and the used HDD-correction overcompensates this, the Finnish space heating consumption is a bit exaggerated in 2015 compared to 2000.

5.5.2 Electricity use per employee

The best level is shown by Romania, the UK and Hungary. Sweden is 19th and Finland 29th. If we look at electricity per floor area, Finland is now much nearer Sweden, only 10% higher, when it was 65% higher in relation to employees. UK is also much closer, and Finland would now be even higher than Spain (now #6).

If we look at service sector non-thermal electricity use per population, we see that Norway, Luxembourg and Finland have the highest unit consumptions, 5, 4 and 3 MWh/person respectively. One suspicion is that part of the electricity use categorised here as non-heating use might actually be for heating.

For electricity use scoreboard trend, Sweden, Hungary and Luxembourg top the list. Finland is 15th. If we look at non-thermal use of electricity, only five countries have experienced a decrease since 2000: UK (-18%), Hungary (-10%), Germany (-6%), Switzerland (-5%) and Sweden (-5). Most countries have increases in tens of percent, e.g. Finland 30%, and the average over all the countries is 42%. Luxembourg and Sweden top the list of employee increase percentage. Hungary is in the middle mass and Finland is 22nd. Greece, Italy, the Netherlands and France, for example, have lower employee increases than Finland. They situate also worse on the trend ranking scoreboard. The trend score might well be more a mirror of personnel and wage developments than of energy efficiency.

5.5.3 In conclusion

ODYSSEE scoreboard for service sector is not very useful as thermal use is estimated per person, not per floor area. Finland would fare much better if floor area were used as basis. As 2015 was warmer than 2000 and the correction according to heating degree-days overcompensates this, the trend score seems to be worse than it is.

In Finland, water heating forms a very large share of total heating demand in the service sector, 40%, which seems to be rather large compared to all other countries. This has a negative effect on Finnish scores on the level scoreboard.

As for heating, Finland would fare better if electric energy was looked at in relation to square metres and not employees.

Overall, services is such a diverse sector that it is really dangerous to compare energy efficiencies of different countries without more disaggregate data available.

6. MURE Policy Scoreboard and Combined scoreboard

MURE is a database of energy efficiency policy measures. The focus of MURE (2017) is on energy efficiency in end-use sectors.

According to ODYSSEE-MURE (2018), the objective of the energy efficiency scoreboard tool is to assess and score the energy efficiency policies of the EU28 by country and by sector (households, transport, industry and services). There are four main scoring approaches: Output-based scoring either based on energy savings, related to energy efficiency potentials or correlated to 2020 energy efficiency targets and an input-based scoring.

The output-based scorings use information in the MURE database on energy savings (“policy output”) and compares the savings with the

- final energy consumption of the sector or total final energy consumption for a given year (at present 2010; by default the scoring period comprises measures from 2000 to present).
- energy efficiency potentials at the time horizon 2030. By default the scoring period comprises measures from 2013 to present. The energy efficiency potentials used have been established in a study by Fraunhofer et al. (2014) for the European Commission in the frame of discussions on the 2030 frame for energy efficiency, renewables and greenhouse gases.
- energy efficiency targets at the time horizon 2020. By default the scoring period comprises measures from 2013 (the starting year of the Energy Efficiency Directive (EED)) to present. Either national value or 20% is used.

The information on impacts in terms of energy savings for each measure in the MURE database may take two forms: 1) Quantitative information from dedicated evaluations of measure impacts, mostly from evaluations at national level, or 2) Semi-quantitative expert estimates on impacts by 3 groups, a) saving less than 0.1% of the sector energy consumption (low impact measures), saving 0.1 to less than 0.5% of the sector energy consumption (medium impact measures), and saving more than 0.5% (high impact measures).

These estimates have been made by the National Teams in the MURE project. Nearly 90% of all measures in the database have been semi-quantitatively classified, and in addition, 40% have a quantitative policy impact evaluation.

The input-based scoreboard uses information on the inputs to energy efficiency policies (e.g. amount of final subsidies) and normalizes the inputs with respect to the size of the country (e.g. Gross Domestic Product). By default the scoring period comprises measures from 2000 to present.

6.1.1 Measures data

MURE Database comprises around 2400 policy measures (MURE 2018b). What measures are included and how is not an easy task. Energy savings should be inserted as cumulated savings in a certain year (NEEAP) and not as lifetime cumulated savings over a time period (EED article 7) (MURE 2017).

Even though the user can change the time frame of interest for the policy scoreboard, the option is open only from year 2000 onwards, earlier years cannot be selected. This leaves out the early savings from energy audits and energy efficiency contract activities that started already in the nineties in Finland.

Data input instructions (MURE 2017): *Please use period (",") as the decimal separator and not "."!* This point is in bold, but it is difficult to interpret, period.

Although there exist strict guidelines, for example NEEAP saving estimates should be used as such, the data seems to be dependent on the data inserter's estimations and evaluations. The measures in the database are also a result of the activity of inserter. Here, national differences might occur for several reasons; lack of funding, lack of responsible party, lack of knowledge or lack of savings assessing methods. Personalities might also come in the picture. Some are eager to have a large and impressive showcase, some are scientifically careful with their estimates or do not want to put down any numbers, and so on.

A lot of measures are cross-cutting, and there are rules how they should be inserted and how they will be estimated. This might affect sectoral results, so sector results cannot directly be compared to similar sector results by the ODYSSEE scoreboard.

6.1.2 Results

A summary of the country rankings based on output score are presented in Table 19.

Table 19. MURE Scoreboard rankings for output based scoring (Data source: MURE 2018a)

Output based scoring	Total	Households	Tertiary	Industry	Transport
/energy savings	1.Germany 2.Ireland	1.Germany 2.Finland	1.Ireland 2.Romania	1.Denmark 2.Romania	1.Spain 2.Italy
Finland Sweden	8 31	2 29	17 29	6 31	8 19
/energy eff potential 2030	1.Denmark 2.Italy	1. Finland 2.Lithuania	1.Denmark 2.Ireland	1.Denmark 2.Italy	1.Spain 2.Italy
Finland Sweden	4 31	1 29	14 29	7 31	4 24
/efficiency target 2020	1.Denmark 2.Italy	1.Germany 2.Finland	1.Ireland 2.UK	1.Denmark 2.Italy	1.Spain 2.Italy
Finland Sweden	8 31	2 29	19 29	3 31	7 23

Finnish positioning is quite well except for the tertiary sector. We can see that in Finland, the household sector is better on the attack, while the service sector presents relative small savings. This is the result of Finnish building sector NEEAP-4 savings being fully allocated to household sector in MURE and not service sector, because the actual allocation is not known, although both are beneficiaries.

Denmark is succeeding quite well. If we look at larger measures performed (MURE 2018c) by Danish authorities, we find measure DK10, with at best a 14% cross-cutting saving. However, this is related to a 1989 decision to forbid electric heating in locations where district heat or gas networks are close, with some update in 2000. This affects the use of primary energy in the energy conversion sector and especially in District heat production and the effects for the end-user sector's energy efficiency is actually quite small. Another Danish measure is DK5 (2014), targeting a 16% savings in the industry. The description, however, is mainly about converting to renewable energy or connecting to district heating and that "An ex-ante analysis shows that result of the measure is a reduction of use of fossil fuel on approximately 16 PJ/year until 2020". Now, this amount has been inserted as an energy efficiency improvement. Actually, as phase 1 of the program targets converting fossil fuel boilers to biomass or biofuel based ones, energy efficiency might actually decrease. Phase three has investment support for energy efficiency improvements related to this. All in all, the savings will be a small share of 16 PJ, perhaps 10 % or even 20% if flue gas condensers are supported, but not 16 PJ.

Output scores based on energy savings are shown in Figure 20. Germany and Ireland are in the lead, with Finland as #8 and Sweden the last one, #31. If we only look at NEEAP (1,2 and 3) measures, Finland is in the lead, and Sweden does not show any noticeable results, as does not around half the countries. If we look at EU-related measures, Romania, the UK and Germany are in the lead with Finland in position 12, and Sweden is with the big group who do not show any noticeable measures/savings. The measures are mainly ongoing, although for Spain they are mostly completed. Scoreboard does not show savings from proposed measures.

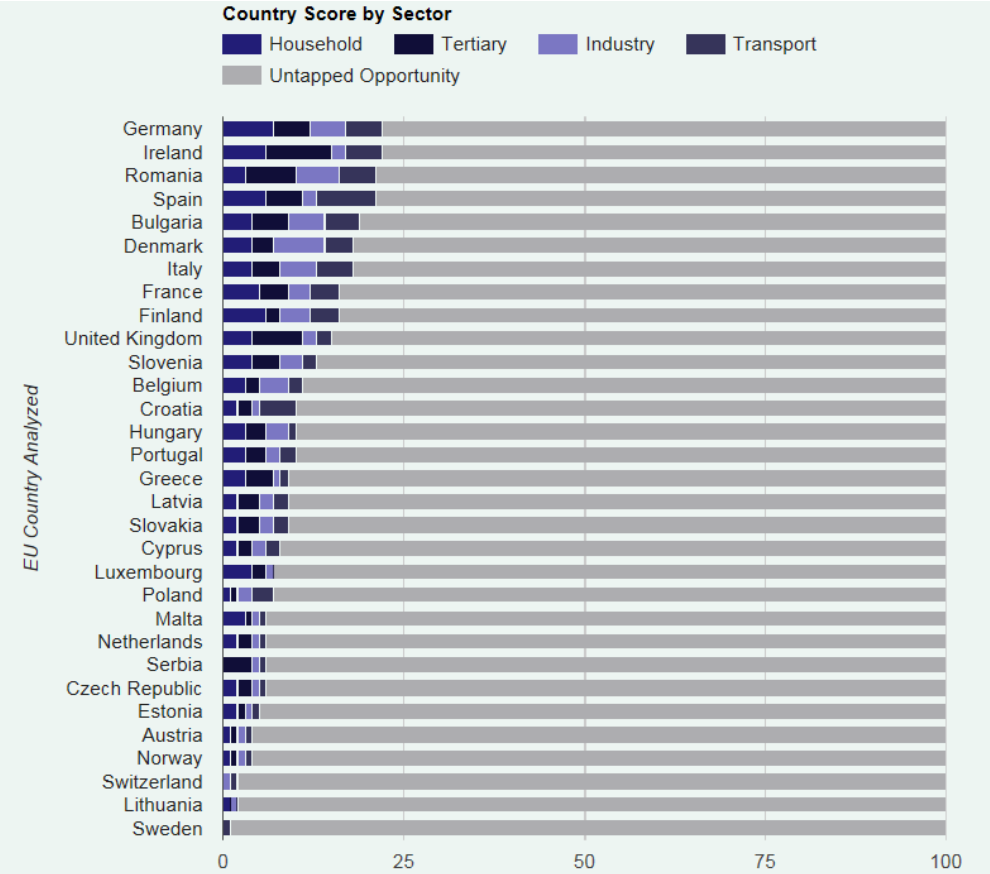


Figure 20. MURE Output scores based on energy savings.(MURE 2018a)

The scores differ a bit if we look at output based scoring related to energy efficiency potentials, see Figure 21. Denmark is in the top, with Italy, Germany and Finland following. Sweden is again in the bottom.

Ireland has large tertiary sector savings, but looking at IRL39 (2018), the reporting system, with encouragements to energy efficiency improvements, by the Sustainable Energy Authority of Ireland seems to bring results. Irish cross-cutting measure (IRL8 2018) is a purely power generation sector measure and as such shouldn’t be in MURE. It has some peak-load cutting issues to a small part, but that is not really energy saving as it in most of the cases relate to energy use timing. The 18PJ savings in 2020 have in practice nothing to do with the end-user sector, so their effects cannot be seen in ODYSSEE scoreboard.

Malta has the most impressive savings bringing measure in the database, MA10 (2013). According to MURE (2018c), savings will be 36% in the household sector, but this effect is not seen in Figure 20. MA10 is a M€21 PV subsidy scheme, co-financed to 85% by European Regional Development Fund. The savings are proposed to be 1.09PJ, but somehow this seems a high number. Looking at the details, the support could add up to 10-20 MWp of PV capacity. Could 1.09 PJ be a typo and the right number 0.19PJ or 0.09, which matches the results presented in the MURE Scoreboard?

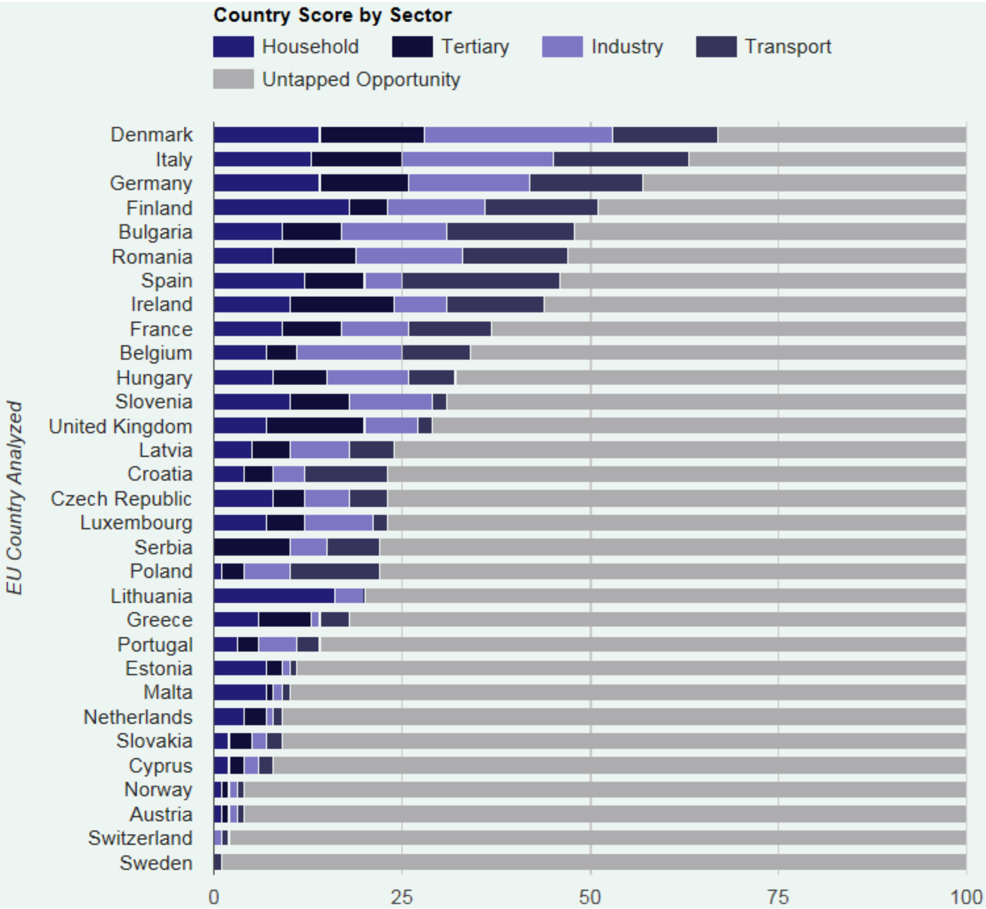


Figure 21. MURE Output based scoring related to energy efficiency potentials. (MURE 2018a)

Results for output based scoring related to energy efficiency target is presented in Figure 22. Of course, the results might differ according to what is selected as target, EU-wide 20% or national target. Denmark is the best performer and especially in the industry sector. The industry savings are quite large compared to other sectors, taking into account that Denmark does not have any energy intensive industry. As already mentioned, DK5 is in reality much smaller. If they support for example flue gas condensers in the new biomass boilers, energy savings for that might well be 20%. Changing to district heating will reduce final consumption of industry with the amount of the boiler losses, as a guess 10-20%, although primary energy savings in Denmark will not necessary be that large, if the boiler losses are just moved to the other side of the balance line.

Looking at some industry measures in Ireland, we see that they mainly concern the energy conversion sector statistically. IRL9 (2012) is a demand response project, which helps balance the power system. Savings might be had on the demand side, or mainly just load displacements, but these are rather small and the efficiency improvements concern mainly the power sector. IRL11 was a mainly industrial boiler to CHP conversion project. Although (primary) energy savings of 165 GWh are booked and are realistic, this effect will not be seen in ODYSSEE end-user energy statistics.

Romania's RO12 (2014) gives savings equating to 140 000 tep, which is 0.14 Mtoe, and further 6 PJ. In MURE (2018c), the savings are given as 40.95 PJ. A question of lifetime cumulative versus cumulative annual savings?

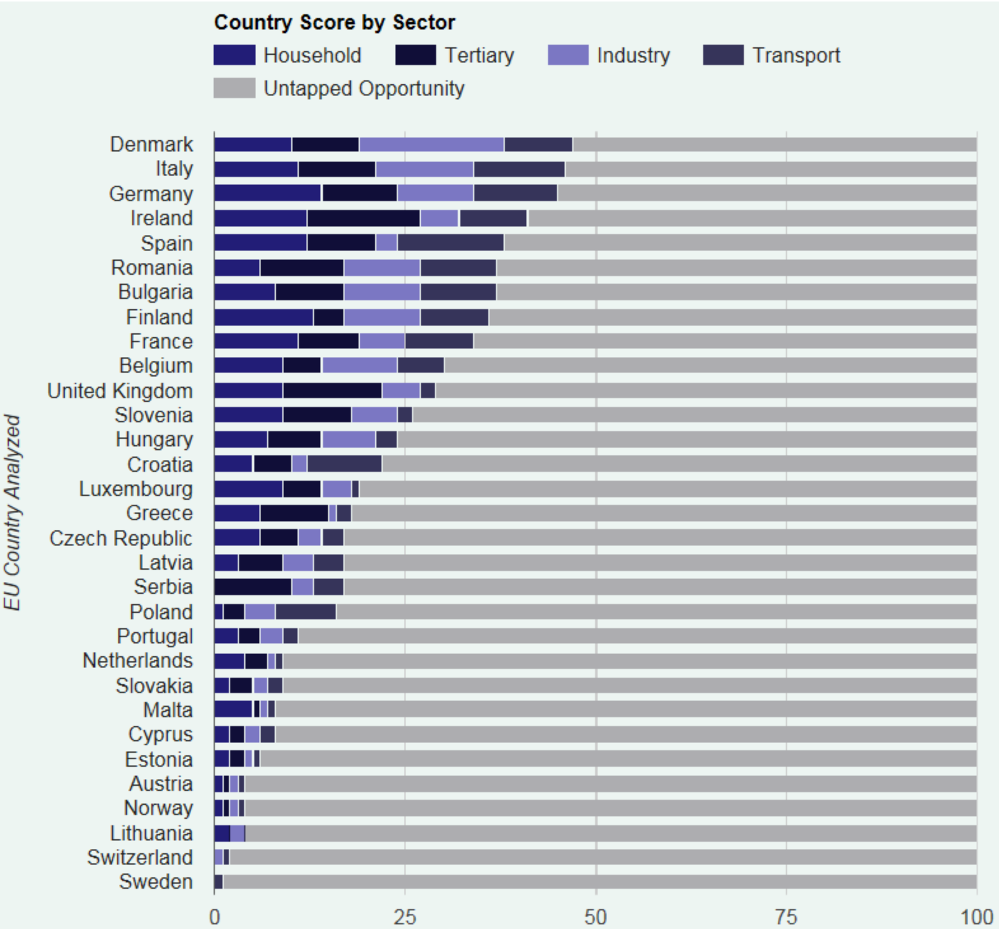


Figure 22. MURE Output based scoring related to energy efficiency target. (MURE 2018a)

In input based scoring, Bulgaria is in the top and Spain second. Finland is 19th , together with 12 other countries that have no points. Sweden is surprisingly 9th.

6.1.3 Conclusions on MURE Policy Scoreboard

A scoreboard is dependent on, and not better than the data it can utilize. MURE database data is extensive, with 2400 measures. All the national data are not similar; for example, Sweden shows very low savings, but that result is not believable. Spain has mainly completed measures, while all others have ongoing. Interesting, and should be confirmed with a further analysis. And as individual measures were looked at, quality issues arose with several of the measures (NB: only nine were looked at more closely). Many were related to the energy conversion sector with only a flimsy tie to the end-user sectors.

A country comparison is useful to be able to see what different countries have registered and how much etc., but it is perhaps not advisable to use it to rank countries with this quality of data. There is a subtle difference between presenting the results for all countries and between saying this is the factual energy efficiency policy ranking of all the countries.

6.2 Combination scoreboard

ODYSSEE and MURE scoreboard results are combined, with a weight of one third to each: ODYSSEE level, ODYSSEE trend and MURE Policy Scoreboard based on energy savings. The credibility of each of these scoreboards differ. The level is mostly based on recent data. The trend is mostly based on the same indicator as the level, but the trend has a greater risk of being "manipulated" by bad data or time series revisions. And the policy scoreboard is based on data of very mixed origin. To have equal weights for each is giving equal credibility and appreciation to each. The author does not succumb to that notion. Anyway, the overall Combined scoreboard results are presented in Figure 23.

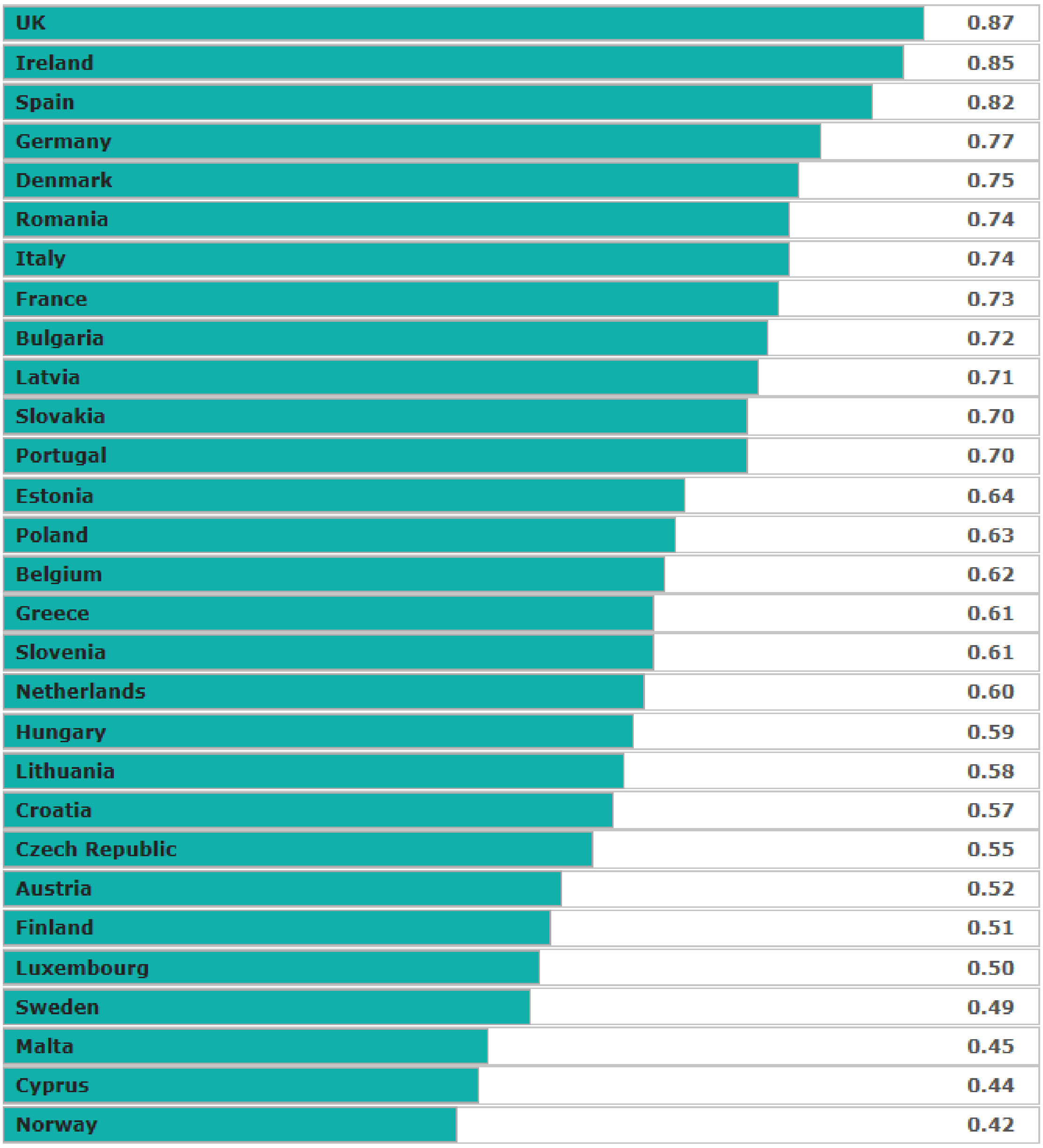


Figure 23. Combined scoreboard total results. (ODYSSEE 2018d)

Finland doesn't fare very well, but Sweden even worse. Finland's Achilles heel is mostly the trend, see Table 20, and if not, vice versa (services). Could one reason be that we have long time series and values available even for year 2000, while many do not, and our initial energy efficiency level was quite high? It is, as already mentioned a few times, easier to introduce hefty changes if the starting level is abysmal. Finnish energy saving contracts were already well in use in the 90's. On the other hand, the economic crisis hit Finland quite hard, tightening the grip on all wallets. Can this have an effect? The scoreboards could actually help to give an answer, if they were better. As it is, methodological weaknesses refrain us from making too bold analyses; the actual trend might well be decidedly better. In general, Eastern European countries are higher up on the trend scorecard and Northern countries more downwards, with, however, UK and Ireland being in #2 and #7 respectively. Ireland benefits also from a lot of energy sector related policy measures. The lack of policy measure input seriously affects Swedish placement.

The input to the Combined scoreboard does not match what is presented in MURE Policy scorecard, so there is a timing issue? For example, looking at Policy scores in Table 20, Finland should be, from top down, 8, 6, 8, 2 and 17. It is a nuisance if ODYSSEE database and the different ODYSSEE scorecards are asynchronous. A reader would benefit a lot from batch updates. Now it hard find out why something is as it is, because the data or the other scorecards are not the same.

Table 20. Combined scoreboard results for Finland and comparison to the best (ODYSSEE 2018d)

		Level	Trend	Policies	Combined
Overall	Finland	20 / 29	29 / 29	9 / 29	24 / 29
	Highest score (benchmark)	UK	UK	Ireland	UK
Industry	Finland	23 / 28	28 / 28	7 / 29	24 / 29
	Highest score (benchmark)	Italy	Lithuania	Denmark	Denmark
Transport	Finland	7 / 29	28 / 29	10 / 29	20 / 29
	Highest score (benchmark)	Italy	UK	Spain	Spain
Households	Finland	5 / 29	27 / 29	3 / 29	7 / 29
	Highest score (benchmark)	Bulgaria	Ireland	Ireland	Ireland
Services	Finland	28 / 29	18 / 29	20 / 29	28 / 29
	Highest score (benchmark)	Lithuania	Hungary	Ireland	Ireland

It is hard to see the benefits of combining these scorecards:

- Sure, the policy measures touch on end-users' energy efficiencies, but to a great extent do not.
- All kind of policies are included, all kind of calculations are included, and probably all kinds of errors are included.
- Trend scores are given equal weights but should be somehow tied to the level. Use of technical ODEX already hides quite a lot of the real industry trend and anyway, ODYSSEE energy saving results are not that trustworthy, as could be seen from the results compared to decomposition analysis done with proper tools.
- As for the level and the trend scores, they are often not based on the best energy efficiency indicator alternative: e.g. solar heat penetration for households, value added for most of industry, employees for service sector must be seen as not the best choices, although, in fairness, for most part of the industry value added is the

only thing we have. Should then most of the industry be compared or not, that is a question.

- For Finland, and Sweden, pulp and paper industry is so dominant when it comes to industry energy use. Without going deeper into the product portfolio, and, what more, only using paper productions as the production basis for the whole industry, leaving pulp out, is not a happy solution. Virgin pulp production is very energy intensive, even using up to three times as much energy as paper or paperboard production.

- In addition, data issues exists. As the rules for how missing data is handled are not published on the site (or just not found?), there is even more questions.

Overall, the ranking of countries tool is really dangerous in the hands of the public, as they probably will not be aware of all the caveats and errors. There should be warning texts that these results do not represent the truth, but only a view and even then without fully adequate data.

7. Conclusions

Traditionally energy intensity, as energy use per gross domestic product, has been used as a simple indicator, but more and more decision makers are being taught that it is not such a good meter. It is a lousy meter as, in fact, IEA and others have noted. Recently, decomposition results by JRC, IEA and ODYSSEE have been presented. These and ODYSSEE and MURE scoreboards are now used to compare nations with each other. This study has looked at the methodologies and data used and at the results.

The title of the report is a question: Energy efficiency: can we easily compare countries? The short answer is no, and here is why not.

7.1 Data issues

As there is serious data issues, both regarding correctness, continuity, and availability at desired disaggregate level, the results of all studies should be read with caution. The indicator definitions used in the analyses are not always the best ways to estimate change in energy efficiency and energy savings. Data availability might be the main driver behind that.

Not all needed data is available. Time series can be missing altogether or be inhabited sparsely with values. What more, how are missing data points or data sets managed? Here, JRC has done a good job in writing out all the assumptions and replacements that have been made in their study. IEA notes when they have made assumptions, but not how, and ODYSSEE stays totally mum on the subject, which is a shame. It would be very important to divulge the basic rules and guidelines used. Any replacement, however, diminishes the usability and comparability of the results. In country rankings and in scoreboards, it can make the difference. Countries which have no data in the database fare better than Finland in the scoreboards, even as Finland does well. Really?

The disaggregate level of data used is a major issue. To get understandable and working indicators, we would need a deep and very detailed disaggregate level. For example, energy intensive sub-sectors should be separated and analysed based on production at an adequate level. On the other hand, the deeper we try to burrow into the data, the less trustworthy it becomes, e.g. splitting electricity consumption into large appliance unit consumptions etc. on an annual basis.

IEA has published the issues that countries have with the data they have delivered. There is a lot of issues, and for example most countries have announced that they are doing or will do something with their transportation data inputs. ODYSSEE has quite well disaggregated and reasonably comprehensive data, with data collection and data structure (and energy efficiency indicator) development going on for years, so it has an advantage to Eurostat or IEA data. However, there is still inconsistencies in the data, and looking over longer periods, there are time series break points where data definitions have changed, and all these affect energy savings estimates.

None of the sources goes any deeper into how end-user direct use energies (especially PV, solar heat, geothermal, heat pump ambient heat) are handled or should be handled in the data. As it is, there is a suspicion that countries might now use different approaches to these. Energies for combined heat and power production are treated correctly by IEA and for the electricity production part also by ODYSSEE, but here sold heat seems to be mistreated.

7.2 Decompositions

Decomposition is an approach that is actually easy to understand and comprehend. Changes in energy use are divided into activity, structure and energy efficiency effects, and these results give valuable insights. Whereas IEA and JRC use a decomposition method where the is no unexplained residue, and the parts form the change of the total, ODYSSEE decomposition is more of a mixture of changes in individual indicators, and the sum of the partial changes is often far from the total change. There is a substantial residue, which reduces the degree to which one can rely on the presented effects being correct. ODYSSE is relying on the concept of a “technical” indicator for savings, i.e. an indicator that only allows for positive developments that increase savings. Methodologically, ODYSSEE is clearly on the losing end.

Looking, for example, at a sector using the same data, transport, and using the same timeline, 2005-2015, JRC and ODYSSEE present quite different decomposition results, with ODYSSEE results being “technically” unrealistic and implausible.

To analyse industry energy use based on added value as JRC and IEA do is an easy solution, but not a very good one. For example, for Finland the ending of Nokia Phones makes a sad impact on the energy intensity. To mix industry, agriculture and especially service sectors is also totally unnecessary and makes the results less useful. Service sector is generally 10 to 20 times larger than the next largest sub-sector, measured in value added, so it totally dominates the results. And as space heating of service sector is not corrected in any way in the comparison, the usability drops even further. However, ODYSSEE separates between industry and service and agriculture sectors and, in addition, looks at energy intensive sub-sectors paper, steel and cement based on physical production. That is an improvement, but not enough, as the disaggregate level is not low enough. Pulp production tons are not used at all, only paper tons, which clearly gives a skewed result. Finland for example exports 27% of the pulp production and most of it to Europe. In addition, to produce pulp from recycled fibres uses 90%-95% less energy than chemical pulp from virgin fibres, so we can’t really compare two societies without knowing what kind of pulp is produced, used, bought and sold, and what kind of paper is produced. For steel, oxygen blown converters and electric arc furnaces are not separated, although it would be fairer.

Households are also not so easy to assess. The definitions of heating degree days differ, space heating corrections to normal climate might be lopsided, e.g. negatively for Finland and positively for Sweden. Large appliance data (IEA, ODYSSEE), which anyhow has a lower trustworthiness in Author’s mind, is not available for all countries. How is missing data handled and is the solution fair? JRC uses gross disposable income for household electricity use. This improves Finnish results, but is it really fair and related to energy efficiency and not to economic prosperity? Italy who fares badly could with good conscience let out a righteous yelp.

The main benefit of decomposition results is that it raises questions: “That is strange, why is this number for this country this high?” The answer to that takes us deeper into the data until we find the underlying reason. It is not so seldom a data, statistics or analysis structure issue. That is the reason for these cautionary words. None of the results by IEA, JRC or ODYSSEE decompositions can be taken at face value. Some results are stronger and more believable, but to recognise them, one needs to understand the caveats behind each study and method.

7.3 ODYSSEE Scoreboards

ODYSSEE scoreboard was also analysed. The scoreboard gives for the transport, household, industry and services sectors scores on both energy efficiency level, trend and their combination. Combining level and trend scores is done with equal weights. This does not feel fair in many cases. Trend is mainly a proportional change in respect to the first year. If the level to begin with is not so good, it is easier to achieve a large change than from a state-of-the-art level. The scoreboard is evaluating a 10% improvement from a bad level as highly a 10% improvement from the state-of-the-art level. Really?

As with the decomposition, there is no clue as to how missing data is managed. This severely hampers the trustworthiness of the scoreboards' results. As country points for individual indicators are scored in relation to the distance from the worst case compared to the distance the best case expresses, outlying worst cases compress the evaluations for all other countries. A good country does not get the point difference it deserves compared to a mediocre country for that indicator, being a disadvantage. It is also disturbing that indicators do not always have the same values in the database as are used for the scorecard, and this can really distort the results (e.g. outlier value for UK car efficiency).

The selection of indicators is also partly dubious. For example:

- Car efficiency is measured in l/100 km. Different fuel litres have different energy contents, and how is for example electricity converted to litres?
- Solar heat penetration is used as an indicator. As it first of all reduces the amount of energy that is in the statistics for water heating, is it not a redundancy to use it also as a separate indicator? Use of solar water heaters feels also a bit lopsided. They are more economical in the Mediterranean area with better solar conditions than in Northern Europe. On the other hand, heat pumps are also used to generate gratis, renewable heat for water heating. Why is not their penetration included?
- For Finland and Sweden, as pulp & paper represents around half of the total industrial consumption, the adjusted indicator is based on physical quantities instead of value added. However, only paper production is used, not physical production of pulp. As pulp and paper has such a tremendous importance for Finnish industrial energy use, any methodological shortcoming such as this will seriously affect the comparability and usability of the results.
- Industry (except pulp and paper) is based on added value. The rise and demise of Nokia phones has a really bad statistical effect on industry trend.
- Air transport is evaluated in energy per passenger. Really? What more, data reveals that this includes both domestic and international flights. Is this really a fair method, as some are situated in the periphery, a long way from Brussels, while others are in the middle of Europe? Finnair of Finland has serious market activity in flights to Far East, which will affect the energy used per passenger.
- Service sector is estimated per employee. This does not measure energy efficiency but labour policies and automation etc. Electric heating scrambles the results for countries such as Norway that do not compile statistics of space heating in the service sector.

7.4 MURE and Combined Scoreboard

After a swift analysis of only nine of 2400 measures used by MURE policy scoreboard, grave doubts on the presented end-user sector energy savings have arisen. Most measures concern the energy transformation sector and their effects can be seen in primary energy use, but at best only lightly touch upon end-user sectors. However, as cross-sector measures, the savings are seen in the scores of all the sectors.

Finland fares well in most sectors' policy scoreboards, but Sweden does not. Sweden is among the last countries. That is not believable. The variation in data input quality and quantity tells us that we really should be careful about ranking countries based on the data.

The Combined scorecard gives equal weights to ODYSSEE level, ODYSSEE trend and MURE Policy scoreboards. The credibility of each of these scoreboards differ. The level is mostly based on recent data. The trend is mostly based on the same indicator as the level, but the trend has a greater risk of being twisted by bad data or time series revisions. And the policy scoreboard is based on data of very mixed origin. To have equal weights for each is giving equal credibility and appreciation to each. The author does not succumb to that notion. In addition, Policy Scoreboard results should correlate with the other Scoreboard results, so there is a bit of redundancy and amplification in using both together.

Finland's overall ranking is 24th of 29, with industry at 24th place, transport at 20th, households at 7th and services at 28th. As could be shown, in many cases Finnish ranking would and should be higher but methodological weaknesses or data uncertainties and revisions gave another result. So, an official ranking of countries should not be done as the results are ever so often too far from the "truth".

7.5 Recommendations

The political demand, and thus the drive, is pushing hard for easy, one-number-says-all, comparative indicators and ranking systems of the energy efficiency development and level of a country. That is the reason why the energy efficiency research community should be careful and actually not present such. The rankings and indicators are all flawed, some more, some less, and full of caveats. And in the worst case, they do not always measure energy efficiency, but other issues.

To compare countries with each other is something that should not be made without excellent and detailed tools. The ODYSSEE Scoreboard is too simplified and misaligned to present a trustworthy result. Overall, the tool for ranking of countries is really dangerous in the hands of the public, as they probably will not be aware of all the caveats and errors. There should be warning texts that these results do not represent the truth, but only a view and even then without fully adequate data behind it.

Nevertheless, ODYSSEE and MURE Scoreboards form a great introduction to the world of energy efficiency. To present all the countries in one picture should actually be the beginning of the journey into energy efficiency comparisons, not the end. To see how one's country compares to others should induce the interest to go deeper, find out the reason why.

Some recommendations for quick improvements:

- add explanations of how missing data and data series are handled,
- add explanations on the indicators used and the data behind them,
- change indicators in use, especially for the ODYSSEE scoreboards,
- do not use equal weights for trend and level and/or readjust trend to take into consideration the level,
- add warnings that any results are not the truth but one view,
- skip the Combined ODYSSEE&MURE Scoreboard, and
- stop using technical ODEX.

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Appendix A

Table A1. Scoreboard indicators for transport sector (ODYSSEE 2018f).

TRANSPORT	Indicators									
	CARS		TRUCKS		AIR		MODAL SPLIT			
	Specific consumption of cars	**Trend**	**Road freight per tkm**	**Trend**	**Air per passenger**	**Trend**	**% public transport**	**Trend**	**% rail & water (freight)**	**Trend**
Countries	l/100 km	trend (00-15)	goe/tkm	trend (00-15)	koe/pass	trend (00-15)	%	trend (00-15)	%	trend (00-15)
aut	7,1	-0,8%	0,030	-1,1%	0,026	-2,5%	25	0,2%	31	-0,2%
bel	7,3	-0,8%	0,051	-1,7%	0,047	-2,4%	20	1,0%	23	-0,5%
bgr	7,8	-0,6%	0,025	-3,8%	0,078	-0,1%	21	-4,4%	13	-8,1%
cro	6,9	-1,1%	0,051	-0,4%	0,070	-0,1%	21	-1,3%	18	-1,6%
cyp	8,9	-0,1%	0,299	2,7%	0,033	-2,3%	18	-1,3%	0	0,0%
dnk	7,7	-0,9%	0,024	-0,2%	0,069	-2,0%	20	-0,2%	10	1,6%
eso	7,8	-0,4%	0,042	0,5%	0,045	-3,3%	21	-2,7%	37	-3,9%
esp	7,0	-0,6%	0,046	-0,6%	0,039	-2,3%	21	-0,1%	17	1,5%
fin	6,7	-0,3%	0,072	2,9%	0,038	0,1%	15	-0,7%	35	0,9%
fra	6,5	-0,9%	0,068	0,2%	0,047	-2,1%	19	1,3%	18	-1,8%
gbr	5,9	-1,8%	0,083	1,0%	0,084	-1,8%	15	1,1%	13	1,4%
grc	6,7	-1,3%	0,104	2,4%	0,021	-6,1%	20	-2,3%	1	0,0%
hun	7,8	-0,6%	0,038	-3,2%	0,062	-7,4%	35	-0,9%	24	-2,2%
irl	7,5	-0,6%	0,096	2,5%	0,028	-2,1%	17	-0,3%	1	-11,9%
ita	6,0	-1,2%	0,099	3,5%	0,025	-2,9%	20	1,3%	14	1,2%
lat	7,8	-0,9%	0,025	-5,5%	0,037	-5,7%	17	-2,1%	58	-1,5%
lth	7,8	-0,9%	0,021	-4,6%	0,078	2,2%	11	-0,5%	34	-3,0%
lux	6,1	-1,5%	0,031	5,8%	0,168	-0,9%	17	1,8%	6	-4,5%
mlt	8,9	-0,1%	0,260	0,1%	0,026	-2,8%	17	-1,1%	0	0,0%
nld	7,5	-0,6%	0,057	-0,4%	0,060	-2,1%	17	0,3%	54	0,5%
nor	7,2	-1,5%	0,076	0,2%	0,033	-1,9%	11	-0,9%	13	-0,2%
pol	7,5	-0,5%	0,025	-3,1%	0,025	-6,3%	23	-3,7%	16	-6,3%
prt	6,7	-1,1%	0,046	-3,6%	0,033	-1,8%	11	-0,2%	7	-0,7%
rcz	7,5	-0,5%	0,031	1,7%	0,056	-0,2%	34	0,1%	21	-2,7%
rfa	7,3	-0,8%	0,032	-1,5%	0,047	-1,7%	15	-0,2%	27	-0,7%
rom	7,8	-0,6%	0,058	-2,1%	0,020	-1,8%	30	-0,7%	41	-2,1%
rsl	6,8	-0,5%	0,032	-0,5%	0,068	-6,4%	24	-2,0%	23	-4,7%
slo	7,4	-0,3%	0,021	-3,3%	0,024	-1,5%	5	-2,7%	19	-2,9%
sui	8,1	-1,7%	0,066	-0,7%	0,036	-2,1%	21	1,1%	38	-0,7%
swe	7,0	-1,6%	0,051	1,0%	0,028	-2,0%	18	0,9%	40	-0,3%

Table A2. Scoreboard indicators for household sector (ODYSSEE 2018f).

	Heating per m2 adjusted to EU climate	Trend- Heating	Other thermal uses	Trend - Other thermal use	Appliances (incl. Lighting and AC)	Trend - Appliances	Solar Water Heater penetration
Countries	koe/m2	trend(00-15)	toe/dw	trend(00-15)	toe/dw	trend(00-15)	% dwelling
aut	10,68	-0,03	0,26	-0,01	0,27	0,01	19,4%
bel	22,05	-0,03	0,23	-0,01	0,23	0,01	2,8%
bgr	10,47	-0,01	0,09	-0,02	0,17	-0,01	0,4%
cro	29,46	-0,03	0,27	-0,01	0,23	0,01	2,0%
cyp	16,76	-0,03	0,34	-0,01	0,27	-0,01	73,2%
dnk	10,09	-0,01	0,31	-0,01	0,24	0,00	7,2%
eso	11,08	-0,02	0,45	-0,01	0,09	0,01	0,3%
esp	9,45	-0,04	0,19	-0,02	0,25	0,02	4,4%
fin	7,32	-0,01	0,30	0,00	0,32	-0,01	0,4%
fra	12,34	-0,02	0,22	-0,01	0,21	0,00	2,3%
gbr	10,22	-0,03	0,22	-0,03	0,25	-0,01	0,7%
grc	18,35	-0,03	0,15	0,00	0,22	0,01	30,2%
hun	17,58	-0,01	0,28	-0,03	0,13	0,00	0,8%
irl	7,95	-0,04	0,32	-0,02	0,19	-0,01	4,0%
ita	15,43	-0,01	0,23	-0,01	0,18	0,00	3,6%
lat	12,67	-0,04	0,37	0,02	0,13	0,03	0,5%
lth	10,46	-0,01	0,15	0,01	0,14	0,03	0,2%
lux	13,13	-0,02	0,19	-0,02	0,26	0,00	5,2%
mlt	14,50	0,00	0,17	0,00	0,21	-0,02	9,8%
nld	8,17	-0,04	0,22	-0,02	0,24	0,00	4,1%
nor	6,99	-0,02	0,25	0,00	0,38	0,00	0,0%
pol	13,18	-0,02	0,33	0,00	0,13	0,01	1,8%
prt	11,09	-0,04	0,38	-0,02	0,12	0,00	6,4%
rcz	12,98	-0,02	0,37	0,00	0,12	0,01	3,9%
rfa	11,50	-0,03	0,30	0,02	0,17	0,00	4,9%
rom	18,74	-0,05	0,44	-0,01	0,12	0,03	0,3%
rsl	9,08	-0,04	0,30	-0,01	0,21	-0,01	1,5%
slo	13,49	-0,01	0,29	-0,01	0,14	-0,01	4,5%
sui	9,11	-0,03	0,25	-0,01	0,22	0,00	10,0%
swe	6,56	-0,02	0,21	0,00	0,48	0,00	1,8%
Source: ODYSSEE							

Table A3. Scoreboard indicators for industry sector (ODYSSEE 2018f).

INDUSTRY	Indicators	
	Adjusted energy intensity	**ODEX 2015**
Countries	koe/€2005p	2000=100
aut	0,13	85
bel	0,12	64
bgr	0,28	44
cro	0,12	72
cyp	0,15	59
dnk	0,10	76
eso	0,13	50
esp	0,11	77
fin	0,19	89
fra	0,12	83
gbr	0,09	67
grc	0,15	71
hun	0,21	59
irl	0,18	60
ita	0,08	77
lat	0,12	53
lth	0,08	38
lux	0,21	73
mlt	n.d.	n.d.
nld	0,13	67
nor	0,28	79
pol	0,09	49
prt	0,14	76
rcz	0,11	64
rfa	0,12	88
rom	0,24	60
rsl	0,12	53
slo	0,11	71
sui	0,06	68
swe	0,13	83
Source: ODYSSEE		

Table A4. Scoreboard indicators for service sector (ODYSSEE 2018f).

SERVICES	Indicators			
	Thermal use consumption adjusted to EU limate	**Trend - Thermal use consumption**	**Specific electricity consumption**	**Trend - Specific electricity consumption**
Countries	toe/emp	trend(00-15)	kWh/emp	trend(00-15)
aut	0,59	-1,1%	4 379	-0,8%
bel	0,78	0,1%	5 964	0,8%
bgr	0,20	-0,6%	5 510	0,9%
cro	0,35	-1,1%	5 292	2,5%
cyp	0,19	-5,4%	5 961	-0,3%
dnk	0,45	-0,6%	4 446	-0,5%
eso	0,38	-0,2%	6 562	3,4%
esp	0,37	0,1%	3 888	0,6%
fin	0,70	-0,1%	9 076	0,8%
fra	0,68	-0,8%	3 731	1,2%
gbr	0,44	-2,7%	2 446	0,3%
grc	0,19	1,4%	5 937	1,9%
hun	0,57	-4,2%	2 697	-2,4%
irl	0,47	-3,2%	4 485	-1,0%
ita	0,63	0,3%	5 652	2,5%
lat	0,49	-0,2%	4 561	3,3%
lth	0,31	-0,6%	3 651	2,7%
lux	0,69	-3,8%	6 353	-1,9%
mlt	0,30	12,0%	6 667	2,2%
nld	0,54	-1,5%	4 924	0,9%
nor	0,25	1,2%	12 493	-0,8%
pol	0,44	1,7%	5 309	2,2%
prt	0,20	-5,1%	5 122	0,9%
rcz	0,48	-2,4%	4 790	0,8%
rfa	0,54	-1,8%	3 890	-0,8%
rom	0,39	5,1%	2 329	7,0%
rsl	0,56	-6,2%	5 190	1,0%
slo	0,38	-5,7%	6 264	1,7%
sui	0,50	-2,1%	4 299	-1,6%
swe	0,52	-2,8%	5 502	-2,8%
Source: ODYSSEE				